DECLARATION

I, YOshihoto Shimizu, residing at Shimizu Patent Attorneys Office of 7F Idemitsu-Nagahori Bldg., 4-26, Minamisemba 3-chome, Chuoku, Osaka, JAPAN, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof. I further certify that to the best of my knowledge and belief the attached English translation is a true and correct translation made by me of U.S. Provisional Patent Application No. 60/421,079 filed October 25, 2002.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 7th day of February, 2005

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[Name of Document] Specification

[Title Of Invention] METHOD FOR MEASURING A SHAPE OF A TUBULAR MEMBER, APPARATUS FOR MEASURING THE SAME, METHOD FOR INSPECTING A TUBULAR MEMBER, APPARATUS FOR INSPECTING THE SAME, METHOD FOR MANUFACTURING A TUBULAR MEMBER, AND SYSTEM FOR MANUFACTURING THE SAME.

[Detail Explanation of the Invention]

[0001]

[Field of Invention]

The present invention relates to a method for measuring a shape of a tubular member, such as a substrate of a photosensitive drum for use in copying machines, an apparatus for measuring the same, a method for inspecting a tubular member, a system for inspecting the same, a method for manufacturing a tubular member, and a system for manufacturing the same.

[0002]

[Background Art]

In a tubular body to be used as a rotating member or the like in various machines, it is sometimes required to measure the precision of the shape. For example, in a substrate of a photosensitive drum for use in electrophotographic systems such as copying machines, a tubular body after the tube manufacturing steps is subjected to a shape measuring to keep high precision of the shape.

[0003]

As a method for measuring the shape, there is a method shown in Figs. 17 and 18. In this method, in a state in which the external peripheral surface 12 of portions near both ends of the tubular body 10 are supported by reference rollers 91, displacement measuring devices 92 are brought into contact with three positions on the

longitudinal central portion of the external peripheral surface of the tubular body 10. Then, the tubular body 10 is rotated by rotating the reference rollers 91 to obtain the variation of the detected values of the displacement measuring devices 92. Using the detected values, the displacement at the longitudinal central portions of the external peripheral surface of the tubular body 90 is measured. Such obtained displacement reflects the deflection of the central external peripheral surface with respect to the external peripheral surfaces of the longitudinal end portions of the tubular body 10.

[0004]

In cases where the tubular body 90 is rotatably supported at the inner peripheral surfaces of the end portions, the thickness distribution (unevenness of thickness)of the tubular body 90 affects the accuracy of rotation. Accordingly, in cases where high precision of shape is required, it can be considered that it is evaluated taking account of the degree of unevenness of thickness by measuring the maximum thickness and the minimum thickness of the tubular body 90.

[0005]

Various techniques for measuring a shape of a tubular body are disclosed by, for example, Japanese Unexamined Laid-open Publication Nos. H11-271008, S63-131018, 2001-3369920, H08-141643, H11-63955, H03-113114, 2000-292161 and H02-275305.

[0006]

[Patent Document 1] Japanese Unexamined Laid-open Publication Nos. H11-271008

[0007]

[Patent Document 2] Japanese Unexamined Laid-open Publication No. S63-131018

[0008]

[Patent Document 3] Japanese Unexamined Laid-open Publication No. 2001-3369920

[0009]

[Patent Document 4] Japanese Unexamined Laid-open Publication No. H08-141643

[0010]

[Patent Document 5] Japanese Unexamined Laid-open Publication No. H11-63955

[0011]

[Patent Document 6] Japanese Unexamined Laid-open Publication No. H03-113114

[0012]

[Patent Document 7] Japanese Unexamined Laid-open Publication No. 2000-292161

[0013]

[Patent Document 8] Japanese Unexamined Laid-open Publication No. H02-275305.

[0014]

[PROBLEMS TO BE SOLVED BY THE INVENTON]

However, the method for measuring the shape of the tubular body using the deflection measurement of the external peripheral surface of the tubular body 90 shown in Figs. 17 and 18 and the thickness measurement using thickness measuring devices has the following problems.

[0015]

(1) Since the deflection measurement of the external peripheral surface and the thickness measurement are performed by using different

measuring devices, device differences among the measuring devices, errors arose from the handling of measuring devices and dispersion of the measuring persons will accumulate, which makes it difficult to attain high accuracy of measurement.

[0016]

(2) Although the deflection of the external peripheral surface and the distribution of the thickness may sometimes be set off geometrically, both of them are measured separately. Therefore, the aforementioned circumstances cannot be considered. As a result, there is a possibility that excessive quality is requested.

[0017]

Furthermore, the aforementioned publications fail to disclose techniques capable of measuring deflection of an external peripheral surface of a tubular body easily with high precision.

[0018]

Furthermore, it can be considered to employ a method for measuring a shape of a tubular body using a conventional circularity measuring device. In this case, however, it is required to repeatedly perform every tubular element such that the rotating axis of a measurement table on which the tubular body is disposed and the central axial position of the tubular body to be measured are aligned and that the rotating axis of the measurement table and the central axis of the tubular body are aligned in parallel, which takes a lot of time and trouble.

[0019]

In view of the above-identified problems, the present invention aims to provide a method for measuring a shape of a tubular member capable of measuring the shape with a high degree of accuracy, an

apparatus for measuring the same, a method for inspecting such a tubular member, a system for inspecting the same, a method for manufacturing such a tubular member, and a system for manufacturing the same.

[0020]

[MEANS FOR SOLVING THE PROBLEMS]

The present invention provides the following means. That is:

(1) A method for measuring a shape of a tubular body, comprising the steps of: inserting a pair of expandable clamps in the vicinity of the end portions of the tubular body, expanding the pair of expandable clamps and bringing them into contact with the entire periphery of the internal peripheral surface of the tubular body, rotating the tubular body together with the expandable clamps about a rotational axis of the pair of expandable clamps, and detecting a radial displacement of the external peripheral surface of the tubular body in accordance with the rotation of the tubular body at at least one position fixed in the peripheral direction of the tubular body.

[0021]

(2) The method for measuring a shape of a tubular body as recited in the aforementioned Item 1, the pair of expandable clamps are brought into contact with a supporting positions in the actual use of the tubular body.

[0022]

(3) The method for measuring a shape of a tubular body as recited in the aforementioned Item 1 or 2, wherein the pair of expandable clamps are brought into face-contact with the internal peripheral surface of the tubular body along the entire circumference

thereof with a certain contact width.

[0023]

(4) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 3, wherein the pair of expansion clamps press approximately evenly, radially and outwardly against the entire circumference of the internal peripheral surface of the tubular body.

[0024]

(5) The method for measuring a shape of a tubular body as recited in the aforementioned Item 4, wherein the pair of expansion clamps deform the tubular body outwardly by pressing the internal peripheral surface of the tubular body outwardly.

[0025]

(6) The method for measuring a shape of a tubular body as recited in the aforementioned Item 5, wherein the deformation of the tubular body due to the pair of the expansion clamps is approximately the same as the deformation at the time of actually using the tubular body.

[0026]

(7) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 4 to 6, wherein the pressing force of the expansion clamp pressing the internal peripheral surface of the tubular body is set to be approximately the same as the expanding pressing force applied to the tubular body at the time of using the tubular body.

[0027]

(8) The method for measuring a shape of a tubular body as recited in the aforementioned Item 5, wherein the deformation of the tubular

body by the expansion clamp is smaller than that at the time of using the tubular body.

[0028]

(9) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 4, 5 and 8, wherein the pressing force of the expansion clamp pressing against the internal peripheral surface of the tubular body is smaller than the tube expanding pressure applied to the tubular body at the time of using the tubular body.

[0029]

(10) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 5 to 9, wherein the tube deformation by the expansion clamp is performed within the elastic deformation region of the tubular body.

[0030]

(11) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 5 to 9, wherein the tube deformation by the expansion clamp is performed until it reaches the elastic deformation region of the tubular body.

[0031]

(12) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 11, wherein the expansion clamp is configured to be expanded by fluid pressure.

[0032]

(13) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 12, wherein the expansion ring is provided with an elastic expansion ring to be radially outwardly expanded by fluid pressure so as to be brought into contact with the internal peripheral surface of the tubular body.

[0033]

(14) A method for measuring a shape of a tubular body, comprises: inserting a pair of expandable clamps into the inside of vicinities of both end portions of the tubular body; expanding the pair of expandable clamps to thereby bring the pair of expanded clamps into contact with internal peripheral surfaces of the tubular body along entire circumference thereof; rotating the tubular body together with the expandable clamps about a central axis of the pair of expandable clamps as a rotation axis; and detecting radial displacement of an external peripheral surface of the tubular body caused by a rotation of the tubular body at at least one position positioned outside the tubular body and fixed with respect to a circumferential direction of the tubular body.

[0034]

(15) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 14, wherein the pair of expansion clamps are disposed horizontally

[0035]

(16) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 14, wherein the pair of expansion clamps are disposed vertically.

[0036]

(17) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 16, wherein the detecting positions for the displacement include a position other than the positions facing off against the expansion clamps from the outside of the tubular body.

[0037]

(18) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 17, wherein the detecting positions for displacement include a plurality of positions outside the tubular body.

[0038]

(19) The method for measuring a shape of a tubular body as recited in the aforementioned Item 18, wherein the detecting positions for displacement include a plurality of positions different in axial position of the tubular body.

[0039]

(20) The method for measuring a shape of a tubular body as recited in the aforementioned Item 18 or 19, wherein the detecting positions for displacement include a plurality of positions same in axial position of the tubular body but different in circumferential position.

[0040]

(21) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 18 to 20, wherein the detecting positions for displacement include two positions same in axial position of the tubular body but different in circumferential position by a half circumferential length.

[0041]

(22) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 18 to 21, wherein the detecting positions for displacement include an outside position of the tubular body facing off against at least one of the pair of expansion clamps.

[0042]

(23) The method for measuring a shape of a tubular body as recited

in any one of the aforementioned Items 1 to 22, wherein the number of the rotation of the tubular body is one or more.

[0043]

(24) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 23, wherein the detection of the displacement is performed continuously during the entire period or a part of the period for rotating the tubular body.

[0044]

(25) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 23, wherein the detection of the displacement is performed intermittently during the period for rotating the tubular body.

[0045]

(26) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 23, wherein the rotation of the tubular body is intermittently stopped and the detection of the displacement is performed when the rotation of the tubular body is stopped.

[0046]

(27) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 26, wherein the detection of the displacement is performed by using a detecting device which comes into contact with the external peripheral surface of the tubular body.

[0047]

(28) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 26, wherein the detection of the displacement is performed by using a detecting device which

does not come into contact with the external peripheral surface of the tubular body.

[0048]

(29) The method for measuring a shape of a tubular body as recited in the aforementioned Item 28, wherein the detection of the displacement is performed by irradiating light against the tubular body from the outside thereof and detecting the light passed over the tubular body.

[0049]

(30) The method for measuring a shape of a tubular body as recited in any one of the aforementioned Items 1 to 29, wherein the tubular body is a photosensitive dram substrate.

[0050]

(31) A method for inspecting a tubular body, comprising: measuring a shape of the tubular body in accordance with the method of measuring a tubular body as recited in any one of the aforementioned Items 1 to 30; and inspecting based on the measured result whether the shape of the tubular body falls within a predetermined allowable range.

[0051]

(32) A method for manufacturing a tubular body, comprising: inspecting the shape of the tubular body in accordance with the method of measuring a tubular body as recited in the aforementioned Item 31; and judging that the tubular body is a finished article when the shape of the tubular body falls within a predetermined allowable range according to the inspection result.

[0052]

(33) An apparatus for measuring a shape of a tubular body,

comprising: a pair of expandable clamps to be inserted in the vicinity of the end portions of the tubular body and expanded so as to be brought into contact with the entire periphery of the internal peripheral surface of the tubular body; and at least one displacement detecting device provided outside the tubular body for detecting a radial displacement of the external peripheral surface of the tubular body, wherein the displacement detecting device detects the displacement in accordance with the rotation of the tubular body when the tubular body is rotated together with the expandable clamp about a rotational axis around the central axis of the pair of expandable clamps.

[0053]

(34) An apparatus for measuring a shape of a tubular body, comprising: the apparatus for measuring a shape of a tubular body as recited in the Item 33; and a comparative means for inspecting whether the shape of the tubular body falls within a predetermined allowable range based on the displacement detected by the displacement detecting device.

[0054]

(35) A system for manufacturing a tubular body, comprising:

a tube manufacturing apparatus for manufacturing a tubular body;

an inspection apparatus for a tubular body as recited in the aforementioned Item 34;

an acceptance/rejection discriminating means for discriminating that the tubular body is a completed product if the inspection result by the inspection apparatus shows that the shape of the tubular body falls within the predetermined allowable range.

[0055]

(Function)

With the method for measuring a shape of a tubular body according to the present invention, a method for measuring a shape of a tubular body, comprises the steps of: inserting a pair of expandable clamps in the vicinity of the end portions of the tubular body, expanding the pair of expandable clamps and bringing them into contact with the entire periphery of the internal peripheral surface of the tubular body, rotating the tubular body together with the expandable clamps about a rotational axis of the pair of expandable clamps, and detecting a radial displacement of the external peripheral surface of the tubular body in accordance with the rotation of the tubular body at at least one position fixed in the peripheral direction of the tubular body. Therefore, the central axis position of the pair of expandable clamps is located almost at the center of a circle formed by the internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular body. Therefore the radial displacement reflects all

influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body.

[0056]

Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened.

[0057]

Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use.

[0058]

Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement.

[0059]

Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and

then rotate the tubular body together with the expandable clamps to detect the displacement of the external peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as small as possible.

[0060]

In cases where the pair of expansion clamps come into contact the positions to be supported at the time of using the tubular body, the shape measurement can be performed as a reference which is a reference of the rotational operation at the time of the actual use. Accordingly, the measurement under the conditions closer to the actual conditions can be performed.

[0061]

In cases where each expansion clamp comes into face-contact with the entire circumference of the internal peripheral surface of the tubular body with a predetermined contact width, it is prevented the tubular body from being deformed into a shape different from the shape in the actual use due to a partial contact of the expansion clamp against the internal peripheral surface of the tubular body, contributing accurate shape measurement. Furthermore, since no inappropriate deformation will be given to the tubular body, it becomes possible to bring the expansion clamp into contact with the internal peripheral surface of the tubular body with larger pressing force.

[0062]

Furthermore, in cases where the pair of expansion clamps press radially outwardly against the entire circumference of the internal peripheral surface of the tubular body, the pair of expansion clamps

can be assuredly brought into contact with the internal surface of the tubular body, assuredly realizing a state close to the rotational state at the time of the actual use.

[0063]

Furthermore, in cases where the pair of expansion clamps deform the tubular body outwardly by pressing the internal peripheral surface of the tubular body outwardly, the supporting state closer to the supporting state at the time of actually using the tubular body 10 to which flanges are inserted into the vicinity of the end portions of the tubular body can be realized, which in turn can attain the rotating state closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0064]

Furthermore, in cases where the deformation of the tubular body due to the pair of the expansion clamps is approximately the same as the deformation at the time of actually using the tubular body, the supporting state more closer to the supporting state in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body 10. This can attain the state more closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0065]

In cases where the pressing force of the expansion clamp pressing the internal peripheral surface of the tubular body is set

to be approximately the same as the expanding pressing force applied to the tubular body at the time of using the tubular body, this can attain the supporting state more closer to the supporting state at the time of actually using the tubular body to which flanges are inserted into the vicinity of the end portions of the tubular body at the time of using the tubular body, which in turn can attain the rotating state closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0066]

Furthermore, in cases where the deformation of the tubular body by the expansion clamp is smaller than that at the time of using the tubular body, the supporting state closer to the supporting state in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body can be attained. This can attain the state more closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected. Furthermore, since the deformation is smaller that the deformation at the time of the actual use, influences to the tubular body due to the shape measurement can be decreased.

[0067]

Furthermore, in cases where the pressing force of the expansion clamp pressing against the internal peripheral surface of the tubular body is set to be smaller than the tube expanding pressure applied to the tubular body at the time of using the tubular body, the

supporting state closer to the supporting state in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body can be attained. This can attain a rotating state more closer to the rotating state at the time of the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected. Furthermore, since the deformation is smaller that the deformation at the time of the actual use, influences to the tubular body due to the shape measurement can be decreased.

[0068]

Furthermore, in cases where the tube deformation by the expansion clamp is performed within the elastic deformation region of the tubular body, the deformation of the tubular body during the shape measurement returns to the original shape, influences to the tubular body due to the shape measurement can be decreased assuredly.

[0069]

Furthermore, in cases where the tube deformation by the expansion clamp is performed until it reaches the elastic deformation region of the tubular body. In this case, even in cases where a tube deformation reaching plastic deformation is given at the time of the actual use, an appropriate deformation for the shape measurement can be given to the tubular body depending in the degree of the actual deformation.

[0070]

Furthermore, in cases where the expansion clamp is configured to be expanded by fluid pressure, large enough expanding force approximately even in the circumferential direction can be obtained,

causing the clamp to be brought into contact with the internal peripheral surface of the tubular body. Further, sufficient pressing force against the internal peripheral surface of the tubular body can be obtained.

[0071]

Furthermore, in cases where the expansion ring is provided with an elastic expansion ring to be radially outwardly expanded by fluid pressure so as to be brought into contact with the internal peripheral surface of the tubular body, large enough expanding force approximately even in the circumferential direction can be obtained, causing the clamp to be brought into contact with the internal peripheral surface of the tubular body. Further, sufficient pressing force against the internal peripheral surface of the tubular body can be obtained.

[0072]

The method for measuring a shape of a tubular body according to the present invention comprises: inserting a pair of expandable clamps into the inside of vicinities of both end portions of the tubular body; expanding the pair of expandable clamps to thereby bring the pair of expanded clamps into contact with internal peripheral surfaces of the tubular body along entire circumference thereof; rotating the tubular body together with the expandable clamps about a central axis of the pair of expandable clamps as a rotation axis; and detecting radial displacement of an external peripheral surface of the tubular body caused by a rotation of the tubular body at at least one position positioned outside the tubular body and fixed with respect to a circumferential direction of the tubular body. Therefore, the central axis position of the pair of expandable clamps

is located almost at the center of a circle formed by the internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular body. Therefore the radial displacement reflects all influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle

formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement. Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and then rotate the tubular body together with the expandable clamps to detect the displacement of the external peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as small as possible. Furthermore, since the pair of expandable clamps are expanded by fluid pressure applied therein, sufficiently large expansion force can be obtained approximately evenly along the circumferential direction, and therefore the clamps can be assuredly brought into contact with the interior peripheral surface of the tubular body. Furthermore, it becomes possible to obtain sufficient pressing force for pressing the interior peripheral surface of the tubular body.

[0073]

Furthermore, in cases where the pair of expansion clamps are disposed horizontally, the tubular body takes a posture with the axial direction approximately horizontal, and therefore measured result close to that in the use can be obtained in the case where the tubular body is used in this posture.

[0074]

Furthermore, in cases where the pair of expansion clamps are disposed vertically, it is prevented the axial central portion of the tubular body from being bent due to gravity, enabling the original shape to be measured.

[0075]

Furthermore, in cases where the detecting positions for the displacement include a position other than the positions facing off against the expansion clamps from the outside of the tubular body, the displacement of the external peripheral surface considering thickness of the tubular body can be measured.

[0076]

Furthermore, in cases where the detecting positions for displacement include a plurality of positions outside the tubular body, the deflection of the external peripheral surface can be measured at plural positions at the outside of the tubular body. By combining the measured results, the shape of the tubular body can be recognized more concretely.

[0077]

Furthermore, in cases where the detecting positions for displacement include a plurality of positions different in axial position of the tubular body, the deflection of the external peripheral surface can be measured at plural positions different in axial position of the tubular body. By combining the measured results, the change of the shape in the axial direction of the tubular body can be recognized.

[0078]

Furthermore, in cases where the detecting positions for

displacement include a plurality of positions same in axial position of the tubular body but different in circumferential position, by combining the measured displacement amounts detected at these plural positions, the cross-sectional shape at the axial position can be recognized more concretely.

[0079]

Furthermore, in cases where the detecting positions for displacement include two positions same in axial position of the tubular body but different in circumferential position by a half circumferential length, by combining the measured displacement amounts detected at these two positions, the diameter passing these two positions can be obtained. Thus, the shape of the tubular element can be recognized more concretely.

[0080]

Furthermore, in cases where the detecting positions for displacement include an outside position of the tubular body facing off against at least one of the pair of expansion clamps, the thickness of the tubular body contacting the expansion clamp can be detected. By combining this thickness with the detected results at another detecting positions, more concrete tubular body shape can be obtained. For example it is possible to calculate inspection results in accordance with a conventional inspection in which the displacement of the external peripheral surface of another portions with respect to the external peripheral surface at the vicinities of the end portions of the tubular body as a reference.

[0081]

Furthermore, in cases where the number of the rotation of the tubular body is one or more. In this case, the entire circumferential

shape of the tubular body can be detected.

[0082]

Furthermore, in cases where the detection of the displacement can be performed continuously during the entire period or a part of the period for rotating the tubular body, a partial shape change in the circumferential direction of the tubular body can also be detected.

[0083]

Furthermore, in cases where the detection of the displacement can be performed intermittently during the period for rotating the tubular body, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0084]

Furthermore, in cases where the rotation of the tubular body is intermittently stopped and the detection of the displacement can be performed when the rotation of the tubular body is stopped, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0085]

Furthermore, in cases where the detection of the displacement is performed by using a detecting device which comes into contact with the external peripheral surface of the tubular body, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0086]

Furthermore, in cases where the detection of the displacement is performed by using a detecting device which does not come into contact with the external peripheral surface of the tubular body,

the displacement of the external peripheral surface of the tubular body can be detected without harming the external peripheral surface of the tubular body.

[0087]

Furthermore, in cases where the detection of the displacement is performed by irradiating light against the tubular body from the outside thereof and detecting the light passed over the tubular body, the displacement of the external peripheral surface of the tubular body can be detected easily and accurately.

[0088]

Furthermore, as the tubular body preferably applied to the method for measuring a shape of a tubular body according to the present invention, a photosensitive dram substrate can be exemplified.

[0089]

With the method for inspecting a tubular body according to the present invention, a shape of the tubular body in accordance with the method of measuring a tubular body as recited in any one of the aforementioned Items is measured; and based on the measured result it is inspected whether the shape of the tubular body falls within a predetermined allowable range. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0090]

With the method for inspecting a tubular body according to the present invention, the shape of the tubular body is inspected in accordance with the method of measuring a tubular body as recited in the aforementioned method, and it is judged that the tubular body is a finished article when the shape of the tubular body falls within

a predetermined allowable range according to the inspection result. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0091]

With the apparatus for measuring a shape of a tubular body according to the present invention, it comprises a pair of expandable clamps to be inserted in the vicinity of the end portions of the tubular body and expanded so as to be brought into contact with the entire periphery of the internal peripheral surface of the tubular body; and at least one displacement detecting device provided outside the tubular body for detecting a radial displacement of the external peripheral surface of the tubular body, wherein the displacement detecting device detects the displacement in accordance with the rotation of the tubular body when the tubular body is rotated together with the expandable clamp about a rotational axis around the central axis of the pair of expandable clamps. Therefore, the central axis position of the pair of expandable clamps is located almost at the center of a circle formed by the internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected

corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular body. Therefore the radial displacement reflects all influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement. Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and then rotate the tubular body together with the expandable clamps to detect the displacement of the external

peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as small as possible.

[0092]

With the apparatus for inspecting a tubular body according to the present invention, it comprises: the apparatus for measuring a shape of a tubular body; and a comparative means for inspecting whether the shape of the tubular body falls within a predetermined allowable range based on the displacement detected by the displacement detecting device. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0093]

With the system for manufacturing a tubular body according to the present invention, it comprises a tube manufacturing apparatus for manufacturing a tubular body, the inspection apparatus for a tubular body, an acceptance/rejection discriminating means for discriminating that the tubular body is a completed product if the inspection result by the inspection apparatus shows that the shape of the tubular body falls within the predetermined allowable range. Therefore, it is possible to provide a tubular body having sufficient shape accuracy without causing excessive quality.

[0094]

[Embodiments of the Invention]

Hereinafter, a method and apparatus for measuring a shape of a tubular body will be explained with reference to the drawings.

[0095]

Fig. 1 is a front cross-sectional view showing the shape

measuring apparatus 5 for a tubular body for use in a tubular body shape measuring method according to the present invention. Fig. 2 is a side cross-sectional view showing the same. Fig. 3 is a cross-sectional view of an expansion clamp. Fig. 4 is an operation explanatory view. Fig. 5 is an explanatory perspective view showing the using state of the tubular body (work) 10 to be measured. Fig. 6 is a front cross-sectional view showing the using state of the tubular body.

[0096]

<Tubular body>

In the present invention, it is assumed that a tubular body to be measured is a cylindrical member having an internal peripheral surface and an external peripheral surface which are circular in cross-section. Furthermore, the tubular body (work) 10 exemplified in this embodiment is a member which will be used while being rotated in a state in which the opposite ends are supported by flanges 80 and 80 inserted therein as shown in Fig. 5. The positions where these flanges 80 and 80 are brought into contact with the tubular body 10 so as to rotatably support it are, for example, the areas S (areas with hatching lines in Fig. 5) with a width d from both ends of the tubular body 10.

[0097]

As shown in Fig. 6, the flange 80 is forcibly inserted into the end portion 13 of the tubular body 10 while slightly expanding it. Thus, the end portion 13 of the tubular body 10 is slightly expanded in diameter as compared with another portion and the cross-sectional shape is corrected by being inserted by the flange 80

[0098]

As the material of such a tubular body (work) 10, aluminum alloy can be exemplified. However, it is not limited to this and can be various metals or synthetic resins.

[0099]

As the manufacturing method, a combination of extrusion molding and drawing molding can be exemplified as will be described later. However, it is not limited to this and can be any method capable of manufacturing a tubular body, such as extrusion molding, drawing molding, casting, forging, injection molding, cutting or a combination thereof.

[0100]

As such a tubular body 10, in concrete, a photosensitive rum substrate or raw tube for use in copying machines or printers employing an electrophotography system can be exemplified.

[0101]

<Outline>

As shown in Figs. 1 to 4, in the method for measuring a shape of a tubular body according to the present invention, a pair of expandable clamps 20 and 20 are inserted in the vicinities of both end portions of the tubular body 10 and expanded so as to be brought into contact with the internal peripheral surface 11 of the tubular body (work) 10 at the vicinities of both end portions, and the radial displacement of the external peripheral surface 12 of the tubular body 10 is detected by each of displacement detecting devices 30 arranged outside the tubular body 10 while rotating the tubular body 10.

[0102]

<Expansion clamp>

The pair of expansion clamps 20 and 20 define the reference of the shape measurement of the tubular body 10.

[0103]

The pair of expansion clams 20,20 is disposed approximately in parallel, and the tubular body 10 as a shape measuring object is supported approximately horizontally by the pair of expansion clamps 20 and 20.

[0104]

As shown in Fig. 3, each of the pair of expansion clamps 20 and 20 is provided with a cylindrical clamp main body 21 having a larger diameter portion 211 and an expansion ring (cylindrical member) 25 attached to a smaller diameter portion 212 of the clamp main body 25 so as to cover the external peripheral surface of the smaller diameter portion 212.

[0105]

Each of the pair of the expansion clamps 20 and 20 is attached to a rotational driving source 26,26 at the outside of the larger diameter portion 211 of the claim main body 21, so that the expansion clamp 20,20 is supported so as to be correctly rotated about the central axis of thereof, as shown in Fig. 1, etc.

[0106]

Furthermore, at least one of the expansion clamps 20 and 20 is configured such that it can be moved axially outward by a driving means (not shown) so as not to cause an obstruction at the time of setting the tubular body 10.

[0107]

The clamp main body 21 is provided with an oil passage 22 to be filled with operation oil. This oil passage 22 is communicated

with an expansion chamber 223 formed at the inside of the expansion ring 25 via a plurality of passages radially expanding in the smaller diameter portion 212 of the clamp main body 21.

[0108]

This expansion chamber 223 is formed between the external peripheral surface of the smaller diameter portion of the clamp main body 21 and the inner peripheral surface of the expansion ring 25. As will be explained above, operational oil is supplied to the expansion chamber 223 to cause the expansion chamber 223 to be expanded by the operational oil pressure (fluid pressure). To keep the sealed state of the expansion chamber 223 even if the expansion ring 25 is expanded in the radial direction, sealing means are provided at the axial both end portions of the expansion chamber 223.

[0109]

In this embodiment, in concrete, O-rings 24 and 24 are fitted in the grooves formed along the entire circumference of the clamp main body 21 so as to closely come into contact with the external peripheral surface (groove) of the clamp main body 21 and the internal peripheral surface of the expansion ring 25 to seal the expansion chamber 223. This o-ring 24,24 is in an inwardly pressed state by the expansion ring 25 in a normal state. When the expansion ring 25 is expanded in the radial direction, the o-ring 24, 24 deforms so as to increase the external diameter while keeping the close contact with the internal peripheral surface of the expansion ring 25, 25 maintaining the sealing state between the expansion ring 25 and the external peripheral surface of the smaller diameter portion 212 of the clamp main body 67. As a material of the o-ring 24, 24 rubber can be exemplified, but any other material can be employed as long

as it is an elastic material that can be served as the aforementioned o-ring.

[0110]

The oil passage 22 in the larger diameter portion 211 of the clamp main body 21 is communicated with an outside of the clamp main body 21 at the central portion of the external end surface of the larger diameter portion 211. Formed in the end portion of the oil-passage 22 in this larger diameter portion 211 is a female screw portion 221 in which an operation screw 222 is mounted. This operation screw 222 is rotatably driven by an arbitrary amount in either direction by a driving source such as a motor (not shown).

[0111]

In this expansion clamp 20, 20 when the operation screw 222 is advanced in the female screw portion 221 by rotating the rotational operation thereof, the operation oil (fluid) in the female screw portion 221 is forwarded to increase the operation oil pressure (fluid pressure) in the oil passage 22 including the aforementioned expansion chamber 223, forwarding the operation oil in the expansion chamber 223 to cause the expansion chamber to be expanded. In concrete, the expansion of the expansion chamber 223 means that the aforementioned expansion ring 685 expands radially to increase the external diameter to thereby expand in the radial direction.

[0112]

The expansion ring 25 is made of an elastic material having predetermined elasticity. As the material of this expansion ring, metal such as alloy steel, synthetic resin and synthetic rubber can exemplified, but any other material can be employed as long as it is an elastic material that can be served as the aforementioned o-ring.

[0113]

The expansion ring 25 will be evenly expanded in the circumferential direction by receiving the radially outward pressure (operation oil pressure, fluid pressure) of the operation oil when the operation oil is fed into the expansion chamber 223 to thereby increase the external diameter. This expansion deformation causes the external peripheral surface of the expansion ring 223 to be brought into contact with the internal circumferential surface of the tubular body 10 along the entire circumference.

[0114]

This expansion ring 25 has a prescribed length in the axial direction. As shown in Fig. 4 (b), at the time of the expansion, it will be expanded while keeping the same diameter of the external peripheral surface in the axial direction. Accordingly, the tubular body 10 comes into face-contact with the expansion ring 25 in the axial direction with a predetermined contact width. As a result, it is prevented the tubular body 11 from being deformed into a shape different from the shape in the actual use due to a partial contact of the expansion clamp 20, 20 against the internal peripheral surface 11 of the tubular body 10, contributing accurate shape measurement. Furthermore, since no inappropriate deformation will be given to the tubular body 10, it becomes possible to bring the expansion clamp into contact with the internal peripheral surface 11 of the tubular body with larger pressing force.

[0115]

The external peripheral surface of the expansion ring 25 is formed into a sufficiently smooth surface, so that the external peripheral surface can come into close contact with the internal

peripheral surface 11 of the tubular body 10.

[0116]

The pair of expansion clamps 20 and 20 will come into contact with the tubular body 10 at the positions to be supported (within the area S with hatching in Fig. 5) at the time of actually using the tubular body 10. As a result, the portion which will become a rotational reference at the time of actually using the tubular body 10 can be treated as a reference for a shape measurement, realizing measurement in line with the actual use.

[0117]

According to the expansion clamp 20, 20 the expansion clamp 20, 20 will come into contact with the internal peripheral surface 11 of the tubular body 10 along the entire circumference thereof because the expansion rings will be expanded evenly in the circumferential direction. Therefore, the tubular body 10 becomes the supported status under approximately the same condition as in the case where the tubular body 10 is supported by flanges at the time of the actual use. That is, the central axial position of the pair of expansion clamps 20, 20 approximately coincides with the center of the circle formed by the internal peripheral surface 11 of the tubular body 10.

[0118]

In this state, by rotating the pair of expansion clamps 20, and 20 about their central axes, a rotational state extremely similar to the rotational state when the tubular body 10 with the internal peripheral surface 11 supported by flanges is actually used can be realized. The behavior of the tubular body 10 at the time of this rotation becomes nearly equal to the behavior in the actual use. Accordingly, by detecting the displacement of the external peripheral

surface of the tubular body 10 rotated as mentioned above, a deflection in which the curvature and/or the uneven thickness of the tubular body 10, or influence such as a cross-sectional shape (perfect circle) are integrated can be detected.

[0119]

Furthermore, since the pair of expansion clamps 20 and 20 come into contact with the internal peripheral surface 11 of the tubular body 10 along the entire circumference, the central axial position of the pair of expansion clamps 20 and 20 can be more assuredly positioned at the center of the circle formed by the internal surface 11 of the tubular body 10, which can realize the state close to the rotating state in the actual use.

[0120]

Furthermore, since the pair of expansion clamps 20 and 20 come into contact with the internal peripheral surface 11 of the tubular body 10 along the entire circumference, even if the clamps come into contact with the tubular body 10 with larger pressing force, the pressing force can be approximately equally distributed in the circumferential direction, contributing to accurate shape measurement.

[0121]

For example, as a common clamp, there is the so-called divided claw type clamp having a plurality of claws to be brought into contact with the internal peripheral surface 11 of the tubular body 10 by increasing the distance between the adjacent claw portions to support the tubular body 10 with the claws radially outwardly pressing plural portions of the internal peripheral surface 11 of the tubular body 10. In such a divided claw type clamp, since the claws partially come

into contact with the internal peripheral surface, there is a possibility of causing the cross-section of the tubular body 10 to be unevenly deformed in the circumferential direction. Especially, in cases where the tubular body 10 is thin in thickness or soft in material, uneven deformation of the tubular body 10 may occur, resulting in inaccurate shape measurement. To the contrary, according to the expansion clamp 20, 20 for a tubular body shape measuring method of the present invention, since the expansion clamp 20, 20 comes into contact with the entire internal peripheral surface of the tubular body 10, problems inherent in a conventional divided claw type clamp would not occur.

[0122]

Furthermore, since the pair of expansion clamps 20 and 20 are inserted in the tubular body 10 and then expanded therein to detect the displacement of the external peripheral surface 12 of the tubular body 10 while rotating the tubular body 10 together with the expansion clamps 20 and 20, the structure can be simplified. Further, the accumulation of measurement errors can be decreased, resulting in high accuracy shape measurement.

[0123]

Since the expansion clamp 20, 20 is configured to be expanded by fluid pressure (operation oil pressure), sufficiently large expansion force approximately even in the circumferential direction can be obtained. This enables the expansion clamp 20, 20 to press the internal peripheral surface 11 of the tubular body 10 radially outwardly with a large pressing force. Accordingly, the expansion clamp 20, 20 can be brought into contact with the internal peripheral surface 11 of the tubular body 10 assuredly.

[0124]

In this embodiment, the end portions 13 of the tubular body 10 are radially outwardly deformed with an enough large pressing force.

[0125]

The deformation is approximately the same as the deformation caused by being inserted by a flange 80, 80 at the time of using the tubular body 10. This can attain the state closer to the rotating state in the actual use.

[0126]

Furthermore, the pressing force pressing the expansion clamp 20, 20 against the internal peripheral surface of the tubular body 10 is set to be approximately the same as the expanding pressing force applied to the tubular body 10 by being inserted by a flange 80, 80 at the time of using the tubular body 10. This can attain the supporting state closer to the supporting state at the time of actually using the tubular body 10 to which flanges 80 and 80 are inserted into the vicinity of the end portions of the tubular body 10, which in turn can attain the rotating state closer to the rotating state in the actual use.

[0127]

Especially, in the actual use, the cross-sectional shape (internal peripheral circle) of the end portion of the tubular body 10 will be corrected into a nearly perfect circle by being forcibly inserted by a flange 80. The shape measurement of the tubular body 10 can be performed with the end portions of the tubular body 10 corrected, like in the actual use, since the tubular body 10 is expanded by the expansion clamps 66 and 66 expanded evenly with the fluid pressure in the circumferential direction.

[0128]

The deformation of the tubular body 10 by each expansion clamp 20, 20 can be performed so as to fall within the elastic deforming region of the tubular body 10 or reach the plastic deforming region of the tubular body 10 depending on the degree of the deformation of the tubular body 10 at the time of the actual use. If the deformation of the tubular body 10 is performed within the elastic deforming region, the deformation occurred at the time of the shape measurement returns to the original shape, which assuredly can minimize the influence to the tubular body due to the shape measurement. On the other hand, in the case of the deformation reaching the plastic deforming region in the actual use, by executing the expansion deformation, the shape measurement can be performed under approximately the same conditions at the time of the actual use.

[0129]

<Displacement detecting device>

The displacement detecting devices 30 are arranged outside the tubular body 10, and their circumference direction positions of the tubular body 10 (displacement detecting positions 31…,32…) are fixed at least when the tubular body 10 is rotated. In other words, in accordance with the rotation of the tubular body 10, the displacement detecting positions 31 and 32 by the displacement detecting devices 30 advance on the external peripheral surface 12 of the tubular body 10 in the circumferential direction thereof.

[0130]

The radial displacement of the external peripheral surface 12 of the tubular body 10 to be detected by the displacement detecting devices 30 means the so-called deflection (external diameter

deflection).

[0131]

In this embodiment shown in Fig. 1, an embodiment in which five displacement detecting devices 30 are arranged so that five positions different in the axial directional position of the tubular body 10 can be displacement detecting positions 31 and 32 is exemplified.

[0132]

Especially, two outermost displacement detecting devices 30 and 30 are disposed at the positions 31 and 31 facing off against the pair of reference portions 20 and 20 at the vicinities of both ends of the tubular body 10 as displacement detecting positions 31 and 31. At these positions 31 and 31, the thickness of the tubular body 10 pinched by and between the reference portion 20 and the displacement detecting device 30 can be measured.

[0133]

On the other hand, the other three displacement detecting devices 30 are disposed at positions 32 other than the positions 31 and 31 corresponding to the pair of reference portions 20 and 20 as displacement detecting positions. At each of these positions 32, the deflection of the external peripheral surface of the tubular body 10 can be detected.

[0134]

As such deflection detecting device 30, in concrete, it may be appropriate to employ a contact type deflection detecting device in which a contact portion is provided at the external peripheral surface 12 of the tubular body 10 so as to detect the deflection of the external peripheral surface 12 of the tubular body 10 by detecting the movement of the contact portion, and a non-contact type deflection detecting

device, which will be mentioned later, as well.

[0135]

When the tubular body 10 is rotated in a state in which the pair of expandable clamps 20 and 20 are in contact with the internal peripheral surface 11 of the tubular body 10, there will be no radial displacement of the external peripheral surface 12 if the tubular body 10 is perfectly circular in cross-sectional shape. To the contrary, if the tubular body 10 is not perfectly circular, the deviation will be detected as the displacement of the external peripheral surface by the displacement detecting devices 30.

[0136]

(Examples of defective tubes)

Next, examples of typical defections of the tubular body 10 will be explained with reference to Figs. 7 to 9. Then, the measurement of the shape of the aforementioned defective tube as an object to be measured will be explained with reference to Fig. 10 showing graphs each showing the result of the displacement of the external peripheral surface of a tubular body (work) 10 as an object detected while rotating the tubular body 10.

[0137]

In Fig. 10, the horizontal axis denotes a rotation angle of the tubular body (work), and the vertical axis denotes the detected value of the radial displacement of the external peripheral surface of the tubular body 10 to be detected by the displacement detecting devices 30.

[0138]

<Bent tube>

Fig. 7 (a) is a perspective view of a bent tube 101 as a defective

example of the tubular body. The bent tube 101 denotes a tube whose axis is bent. Here, in order to exclude another defective factors, it is assumed that the circle formed by the internal peripheral surface (internal peripheral circle) and the circle formed by the exterior peripheral surface (exterior peripheral circle) in each cross-section are perfectly circular along the entire length, and that the center of the internal peripheral circle and that of the external peripheral circle coincide with each other (concentric), and therefore the thickness of the tubular body is uniform.

[0139]

In the actual use of such a bent tube 101, as explained with reference to Fig. 5, when the tube 101 is rotated by the flanges inserted into both ends of the tubular body, as shown in Fig. 7 (a), the bent tube 101 rotates about the straight line T1 passing the centers of the internal peripheral circles at the vicinities of both ends of the tube 101, causing deflation at the axial central portion of the bent tube 101. The chain double-dashed line in Fig. 7 (a) shows the state rotated by 180 degrees from the state shown by the solid line.

[0140]

Fig. 7 (b) is a cross-sectional view taken at the axial central portion of the bent tube 101, and the chain double-dashed line shows the external peripheral surface (external peripheral circle) in the state rotated by 180 degrees from the state shown by the solid line. As shown in this figure, although the tubular body 101 is pushed up in the state shown by the solid line, it is pushed down when rotated by 180 degrees as shown by the chain double-dashed line, and then it returns to the state shown by the solid line when further rotated

by 180 degrees. That is, 360-degree-cycle deflection is generated.

[0141]

In the rotation using the flanges, the line passing the center of the internal peripheral circle at the vicinity of one end portion of the tubular body supported by the flange and the center of the internal peripheral circle at the vicinity of the other end portion of the tubular body supported by the flange constitutes the rotation axis T1. However, this rotation axis T1 and the center of the external peripheral circle are misaligned at the axial central portion of the bent tube 101. The deflection caused at the central portion in the axial direction of the bent tube 101 arises from the misalignment between the rotation axis T1 determined by the internal peripheral circles at the vicinities of both ends of the tube 101 and the center of the external peripheral circle in a cross-section to be observed.

[0142]

When the shape measurement of the bent tube 101 is performed, since the expandable clamps 20 support the end portions of the bent tube 101 in the same manner as in the flange in the actual use, the bent tube 101 rotates as shown in Figs. 7(a) and 7(b) even at the time of measurement while rotating the tubule about the central axis of the expandable clamps 20.

[0143]

Accordingly, at the displacement detecting positions 32 at the axial central portion of the tubular body 101, i.e., three displacement detecting positions 32 other than the positions 31 facing the pair of expandable clamps 20, the shape measuring method of the tubular body 10 can detect the fluctuations of the external peripheral surface due to the bent of the tubular body 101 as shown in Fig. 10(b).

[0144]

Also at the middle detecting position among the central three deflection detecting positions 32 of the tubular body 10, the largest fluctuations can be detected. By comparing the degree of the fluctuations at each deflection detecting position, it is possible to recognize that the defect of the tubular body 10 is caused by the bent of the tube and also to assume the degree of the bent.

[0145]

On the other hand, at the deflection detecting positions 31 facing the pair of expandable clamps 20, the thickness of the tubular body 10 at the positions 31 is detected. However, since it is assumed that the thickness of the bent tube 101 is constant as mentioned above, the detection results with no change of deflection as shown in Fig. 10(a) can be obtained.

[0146]

<Uneven thickness tube>

Fig. 8 (a) is a perspective view of a tube 102 with uneven thickness as a defective example of a tubular body (hereinafter referred to as "uneven thickness tube"). The uneven thickness tube denotes a tube in which the thickness differs in the circumferential direction at a cross-section of a tubular body. Here, in order to exclude another defective factors, it is assumed that the axis of the tubular body is a straight line, the circle formed by the internal peripheral surface (internal peripheral circle) and the circle formed by the exterior peripheral surface (exterior peripheral circle) are perfectly circular in each cross-section along the entire length thereof, but the center of the internal peripheral circle and that of the external peripheral circle are shifted (eccentric), and

therefore the thickness is uneven. Furthermore, it is also assumed that the cross-sectional configuration is constant along the axial direction of the tubular body and that there is no twist.

[0147]

In the actual use of such an uneven thickness tube 102, as explained with reference to Fig. 5, when the tube is rotated by the flanges inserted into both ends of the tubular body, as shown in Fig. 8 (a), the uneven thickness tube 102 rotates about the straight line T2 passing the centers of the internal peripheral circles at the vicinities of both ends of the tube 102, causing deflation at the entire length of the tube 102 along the axial direction. The chain double-dashed line in Fig. 8 (a) shows the state rotated by 180 degrees from the state shown by the solid line.

[0148]

Fig. 8 (b) is a cross-sectional view of the uneven thickness tube 102, and the chain double-dashed line shows the external peripheral surface (external peripheral circle) in the sate rotated by 180 degrees from the state shown by the solid line. As shown in this figure, although the external peripheral surface of the tube 102 is raised upward as a whole since the thicker portion is located at the upper portion as shown by the solid line, the thicker portion is moved downward when it is rotated by 180 degrees as shown by the chain double-dashed line and the thinner portion is located at the upper position, and therefore the external peripheral surface is moved downward as a whole and then it returns to the state shown by the solid line. That is, 360-degree-cycle deflection is generated.

[0149]

In such a rotation by the flanges, in the same manner as the

aforementioned bent tube, the line passing the center of the internal peripheral circle at the vicinity of one end portion of the tubular body supported by the flange and the center of the internal peripheral circle at the vicinity of the other end portion of the tubular body supported by the flange constitutes the rotation axis T2. In the uneven thickness tube 102, since the center of the internal peripheral circle and that of the external peripheral circle are misaligned along the entire length of the tube, the rotation axis T1 which is determined based on the internal peripheral surface and the center of the external peripheral circle are misaligned along the entire length of the bent 102. The deflection along the entire length of the uneven thickness tube 102 arises from the misalignment between the rotation axis T2 determined by the internal peripheral circles at the vicinities of both ends of the tube 102 and the center of the external peripheral circle at a cross-section to be observed.

[0150]

When the shape measurement of the uneven thickness tube 102 is performed, since the expandable clamps 20 support the end portions of the uneven thickness tube 101 in the same manner as in the flange in the actual use, the tube 101 rotates as shown in Figs. 8(a) and 8(b) even at the time of measurement while rotating the tubule about the central axis of the expandable clamps 20.

[0151]

At this time, at all of the detecting positions, i.e., the detecting positions 31 and 31 at the vicinities of both ends of the tubular body 102 facing off against the pair of reference portions 20 and the detecting positions 32 other than the above detecting positions 31 and 31, as shown by the arrow under the tubular body

102 in Fig. 7B, the external peripheral surface of the tubular body 102 is displaced in the radial direction, and the cycle is 360 degrees. Therefore, according to this method for measuring a shape of a tubular body, deflection of the external peripheral surface due to the unevenness thickness of the tubular body 102 can be detected.

[0152]

Especially, at the detecting positions 31 and 31 facing off against the reference portions 20 and 20, the thickness of the tubular body 102 is directly detected. Therefore, it is possible to obtain the thickness distribution in the circumferential direction of the tubular body 102 from the deflection detected at the positions 31 and 31.

[0153]

Furthermore, although a tubular body generally includes defect factors such as bent or unevenness in a complex manner, according to this method for measuring a shape of a tubular body, a result reflecting these influences can be obtained by one measurement.

[0154]

Furthermore, if it is assumed that the uneven thickness is almost the same along the entire length of the tubular body, it is possible to assume that the thickness distribution in the circumferential direction of the tubular body which will be proved from the displacement detected at the detecting positions 31 and 31 facing off against the reference portions of the tubular body 10 is the same along the entire length of the tubular body 10. In this case, although the displacement detected at the detecting positions 32 other than the detecting positions 31 and 31 facing off against the reference portions 20 includes the displacement due to the uneven thickness,

it is possible to take out only the defective influences due to causes other than the unevenness by subtracting the displacement detected at the detecting positions 31 and 31. By this, regarding a tubular body having defective factors of bent and uneven thickness in a complex manner, it is possible to obtain the results affected by these influences and to evaluate the respective defective degree by separating the influences due to the defectives from the results.

[0155]

Such assumption that such uneven thickness is almost the same along the entire length of the tubular body can be made, in most case, based on the characteristics and the like of the manufacturing method of the tubular body. For example, if the tubular body is manufactured by performing a continuous extrusion and then cutting the extruded member into a predetermined length, there are many cases capable of assuming that the cross-sectional shape is almost the same along the entire length of each tubular body.

[0156]

<Flat tube>

Fig. 9(a) is a perspective view of a tube 103 with a non-perfect circular cross-section as a defective example of a tubular body, especially a tube with a flat cross-section (hereinafter referred to as "flat tube"). The flat tube denotes a tube not having a perfect circular cross-section but having an elliptic cross-section formed by pressing from up-and-down direction or right-and-left direction. Here, in order to exclude another defective factors, it is assumed that the axis of the tubular body is a straight line, the cross-sectional shape of the internal peripheral circle and that of the exterior peripheral circle are almost similar, the thickness is

almost constant, the cross-sectional shape is constant along the entire length with no twist.

[0157]

In the actual use of such a flat tube 103, as explained with reference to Fig. 5, it cannot be decided how the flanges are set with respect to the tubular body (flat tube), or how the position or the posture of the tubular body (flat tube) 103 is decided with respect to a rotation axis as a center of the flange because they are decided based on the relationship of the degree of flatness or the strength of the tubular body, the size of the flange and the strength of the flange. Here, it is assumed that both the flanges are set to both end portions of the tubular body 103 with the center of the flange aligned with the center of the internal peripheral circle of the flat tube. In this state, when the tubular body (flat tube) 103 is rotated, as shown in Fig.9(a), the flat tube rotates about the straight line T3 passing the center of the internal peripheral circle as an axis, causing deflection along the entire axial length of the flat tube 103. The chain double-dashed line in Fig. 9(a) shows the state rotated by 90 degrees from the state shown by the solid line.

[0158]

Fig. 9(b) is a cross-sectional view of the flat tube 103, and the chain double-dashed line shows the external peripheral surface (external peripheral circle) in the state rotated by 90 degrees from the state shown by the solid line.

[0159]

As shown in this figure, although the tubular body 103 is taking a vertical posture in the state shown by the solid line, it will take

a horizontal posture as shown by the chain double-dashed line when further rotated by 90 degrees, and then returns to the original posture shown by the solid line when further rotated by 90 degrees. As will be understood from the above, inward and outward displacements of the external peripheral surface will be repeated, causing 180-degree-cycle deflection.

[0160]

As mentioned above, it is assumed that the rotation axis T3 of this flat tube 103 passes the centers of the internal peripheral surfaces of both ends of the tubular body (flat tube) 103. Furthermore, in this example assuming that the cross-section is constant along the entire length of the tube, the rotational axis T passes the center of the external peripheral circle (not perfect circle) at any cross-section. Therefore, the deflection along the entire length of the flat tube 103 arises from the fact that the external peripheral circle in each cross-section of the tubular body 103 is shifted from the perfect circle.

[0160]

When the shape of such flat tube 103 is measured, the expandable clamps 20 support the end portions of the bent tube 101 in the same manner as in the actual use. In the non-circular cross-sectional tube, such as non-circular flat tube, as mentioned above, it is not decided how the tube is supported by the flanges in the actual use. However, as mentioned above, with the shape measuring method for a tubular body according to the present invention, since the tubular body is supported approximately the same conditions as in the actual use and rotated, irrespective of the support of the tubular body at the actual use, it becomes possible to realize the supporting state and rotating

state during the shape measurement.

[0162]

Here, assuming that both of the expandable clamps 20 are set at the positions corresponding to the center of the interior peripheral circle of the flattened tube 103 in the same manner as in the actual use, the flattened tube 103 rotates as shown in Figs. 9(a) and 9(b).

[0163]

Accordingly, deflection of the external peripheral surface 12 with a 180 degree cycle as shown in Fig. 10(c) can be measured at the detecting positions 31 near the end portions of the tubular body 103 facing the pair of expandable clamps 20 and all of the three central detecting positions 32 other than the above. That is, according to this method for measuring a shape of a tubular body, it is also possible to detect defects due to the fact that the cross-section of the tubular body is non-circular.

[0164]

Furthermore, from the changing status of the displacement to be detected (the shape of the graph in Fig. 10(c)), it is also possible to guess the cross-sectional shape of the measured tubular body 103.

[0165]

Furthermore, although this advanced method can detect the defects such as bent or uneven thickness of the tubular body in the same manner as in the first method, results reflecting the defects due to the non-circular cross-sectional shape and the influences of the defects can be obtained.

[0166]

Furthermore, by considering the typical detection pattern of

each defect, it is possible to discriminate the degree, size or contents (cross-sectional shape in the case of non-circular cross-section) of each defect. This can contribute to countermeasures for solving each defect.

[0167]

<Tubular body with deformed ends>

Next, concrete tubular body shapes will exemplified, explanation will be directed to two cases in which the advantage of the tubular shape measuring method according to the invention can be demonstrated especially.

[0168]

As shown in Fig. 11, in the first example, although only both end portions 13 and 13 of the tubular body 10 have a flat shape respectively, the central portion 14 has an appropriate perfect circular cross-sectional shape.

[0169]

Tubular bodies to be supplied as photosensitive drums or the like are manufactured by cutting a long tubular body substrate into a certain length in many cases. In such cases, only the vicinities of the end portions of the tubular body tend to be deformed into a flat shape by the cutting.

[0170]

In such a shape in which the vicinities of both end portions are formed into a flat shape respectively, when the shape is measured in accordance with a conventional method as shown, for example, in Figs. 17 and 18, it will be judged that the shape is far from the perfect cylindrical shape. In the case of a shape inspection with a certain acceptance level, there is a high possibility that it is

judged to be a defective item.

[0171]

In some cases, however, when flanges are forcibly inserted into both ends of the tubular body in the actual use as shown in Fig. 5, both end portions of a tubular body may be corrected into a perfect circular shape respectively, which resolves the shape defect. Thus, in such cases, it becomes a perfect cylindrical shape in the actual use, causing no problem. On the other hand, in another cases, even if flanges are forcibly inserted at the time of the actual use, a perfect cylindrical shape may not be obtained. Such a tubular body is a perfect defect item. In a conventional shape measuring method, such discrimination was impossible, and therefore there is a possibility that an item to be discriminated as a good item is discriminated as a defect item.

[0172]

To the contrary, in the shape measuring method according to the present invention, the shape measurement of the tubular body 10 can be performed while expanding the shape of both end portions of the tubular body similar to that in the actual use by inserting the expansion clamps 20, 20 into the vicinities of both end portions of the tubular body 106 and expanding it to be brought into contact with the internal peripheral surface of the tubular body 10. Accordingly, even if the tubular body has a false defect which will be dissolved at the time of actually being used at the vicinities of both end portions as shown in Fig. 11, it is possible to obtain a shape measuring result including a discrimination on whether the false defect is a permanent defect which will remain even in the actual use.

[0173]

As a result, an accurate shape measurement of a tubular body which had no choice but to be discriminated as a defect item in a conventional method can be performed, resulting in a perfect shape measuring result.

[0174]

<Tubular body with uneven material distribution>

In the second example in which the advantage of the tubular shape measuring method according to this invention can be demonstrated especially, although it has a perfect cylindrical shape before inserting a flange at the time of the actual use, the material distribution is uneven in the circumferential direction.

[0175]

Fig. 12 shows an example of the tubular body 107 uneven in material distribution in the circumferential direction, wherein Fig. 12(a) shows the state before being inserted by a flange and Fig. 12(b) shows the state after being inserted by the flange.

[0176]

As shown Fig. 12(a), this tubular body is even in thickness along the entire circumference. However, the left half portion W can be easily deformed as compared to the remaining portion. Such a tubular body can be manufactured when there is an irregular flow of the extruding material at the time of extruding the tubular body or when there are irregular environment conditions such as temperature conditions after forming into a tubular body in the circumference direction.

[0177]

Inserting a flange 80 into the tubular body 10 cause the tubular body 10 having an original diameter D of the circle (internal

peripheral surface) as shown in Fig. 12(a) formed by the internal peripheral surface to be expanded into the diameter D' of the circle (internal peripheral surface) formed by the internal peripheral surface as shown in Fig. 12(b) for example. At this time, the easy-to-deform portion W will be stretched largely to thereby become a thin portion W' thinner than the remaining portion.

[0178]

In other words, in the second embodiment, contrary to the first example, the shape will be discriminated as a normal shape before the actual use. However, at the time of the actual use, the end portions of the tubular body supported by at least flanges and determining the rotational center become uneven in thickness as a defect tubular body.

[0179]

In a conventional shape measuring method as shown in Figs. 17 and 18 for example, since such a tubular body has a perfect cylindrical shape at the time of the shape measurement, it would be discriminated that it is a perfect cylindrical shape. Therefore, it was impossible to detect such a defect tubular body.

[0180]

To the contrary, according to the shape measuring method of the present invention, the shape measuring of the tubular body can be performed in the state in which the expansion clamps 20 and 20 are inserted into the vicinities of both end portions of the tubular body 10 and then expanded to be brought into contact with the internal peripheral surface of the tubular body to thereby attain the expanded state closer to the actual use state. This also enables a detection of a hidden defect of the vicinities of the end portions which will

be generated at the time of the actual use, resulting in a perfect shape measurement result.

[0181]

(Inspecting apparatus)

Next, a tubular body inspecting apparatus according to the present invention will be explained.

[0182]

Fig. 13 is a functional block diagram showing the structure of the inspecting apparatus 6.

[0183]

This inspecting apparatus 6 is equipped with the aforementioned automatic shape measuring apparatus 5, a deflection amount calculating portion 61 for calculating the deflection amount of the external peripheral surface 12 from the displacement data of the external peripheral surface 12 detected by the shape measuring apparatus 5, an allowable range storing portion 62 for setting and storing the allowable range of the deflection of the external peripheral surface of the tubular body 10, a comparing portion 63 for discriminating whether the deflection amount of the tubular body 10 calculated by the deflection amount calculating portion 63, and an outputting portion 64 for outputting the inspected result.

[0184]

Concretely, the deflection amount calculating portion 61, the allowable range storing portion 62, the comparing portion 63 and the outputting portion 64 are comprised of software and hardware performing each function in a sequencer, etc., consisting of a computer.

[0185]

The deflection amounts treated in the deflection amount calculating portion 61, the allowable region storing portion 62 and the comparing portion 63 can be the deflection amounts at all five portions or some of them in the case where the displacements of the external peripheral surface 12 at the five portions (five cross-sections) in the axial direction of the tubular body 10 are detected by the shape measuring apparatus 5 for example.

[0186]

Furthermore, even in the case where deflection amounts of plural portions (e.g., five portions) are used, the acceptable condition of the final inspection can be that each of all the deflection amounts fall within the predetermined allowable range or that the combination of the deflection amounts at plural portions falls within the predetermined allowable range. The example of the combination of the deflection amounts is that each of the deflection amount at the plural portions falls within the predetermined range and the total of these deflection amounts fall within the predetermined range.

[0187]

In this embodiment, the calculating means for processing the raw data of the displacement of the external peripheral surface of the tubular body 10 detected by the shape measuring apparatus 5 and calculating the index value or the like showing the shape of the tubular body 10 such as a deflection amount of the external peripheral surface is set outside the shape measuring apparatus 5. However, the shape measuring apparatus 5 can be provided with such a calculating means. Furthermore, the shape measuring apparatus 5 can have an outputting means for outputting the calculated result.

[0188]

(Manufacturing system)

Next, a tubular body manufacturing system according to the present invention will be explained.

[0189]

Fig. 14 is a functional block showing the structure of the manufacturing system 7.

[0190]

This manufacturing system 7 is provided with a tube manufacturing apparatus 71 for manufacturing a tubular body 10, the aforementioned inspecting apparatus 6 and a judging portion 72 for judging whether the tubular body 10 is a completed item based on the inspection result of the inspecting apparatus 6.

[0191]

The tube manufacturing apparatus 721 is an apparatus for manufacturing a tube by combining the extruding and drawing of a photosensitive drum substrate. Concretely, in the case of manufacturing an aluminum alloy photosensitive drum, the apparatus is constituted as an assembly of mechanical devices for carrying a step of manufacturing extruding material by dissolving raw materials, an extruding step, a drawing step, a correcting step, a cutting step for cutting into a predetermined length, a washing step, etc.

[0192]

The tubular body 10 manufactured as mentioned above is inspected whether the shape is in a predetermined allowable range. Based on the inspection result, the judging portion 72 judges the tubular body 10 as a completed item if it falls within the predetermined allowable range.

[0193]

It is preferable that the manufacturing system 7 is provided with an automatic carrying apparatus for automatically carrying the tubular body 10 from the tube manufacturing apparatus 71 to the shape measuring apparatus 5 of the inspecting apparatus 6.

[0194]

Furthermore, it is preferable that the manufacturing system 72 is provided with a carrying apparatus for carrying the completed item judged as an accepted product by the judging portion 72 and the possible defect product to different places.

[0195]

Furthermore, in the tubular body shape measuring apparatus 5 equipped in the inspecting apparatus 6, it is preferable to equip a feedback function for feeding the discrimination of the type or feature of the defect generated in the tubular body 10 back to the tube manufacturing apparatus 71 to prevent the generation of a defected product.

[0196]

(Another embodiments)

Although the present invention was explained with reference to each embodiment, the preferable structure regarding the ninth embodiment can be exemplified as follows.

[0197]

(1) In the above-mentioned embodiment, although the pair of expansion clamps 20 and 20 are brought into contact with the positions to be supported at the time of using the tubular body, they can be brought into contact with any other positions within the internal peripheral surface of the tubular body. It is preferably the vicinity of the portion to be supported since there is a high possibility that

the portion to be supported and the vicinity thereof resemble in cross-sectional shape.

[0198]

(2) In the aforementioned eleventh embodiment, although the shape measurement was performed with the axial direction of the tubular body 10 placed nearly horizontally, the measurement can be performed with the axial direction of the tubular body 10 placed nearly vertically. This decreases the deflection of the tubular body 10 due to its own weight, enabling an accurate shape measurement of the tubular body 10.

[0199]

(3) In the aforementioned embodiment, the displacement of the external peripheral surface was detected at plural cross-sections (axial positions) of the tubular body 10 by disposing one displacement detecting device 30 at each of the plural cross-sections. However, at one or plural cross-sections, a plurality of displacement detecting devices 30 can be placed to detect a plurality of displacements at a single cross-section. In this case, from the plural detected displacements at one cross-section, it becomes possible to grasp the cross-sectional shape more precisely.

[0200]

Furthermore, as shown in Fig. 15, in the case in which the displacements of the external peripheral surface are detected at two positions 31, 32, 33 and 34 (opposing positions) of any cross-section (axial position) of the tubular body 10 different in circumferential position by a half circumferential length, the diameter of the cross-section of the tubular body 10 can be directly obtained. That is, in the case in which the tubular body 10 is rotated about the

central axis of the expansion clamps 20 and 20 with the tubular body 10 supported by the expansion clamps 20 and 20, it is theoretically possible to obtain the diameter of the tubular body 10 by adding the displacement amount at the positions different in rotational angle by 180 degree from the detected displacements of the single displacement detecting device 30. However, the theoretical diameter accuracy will be affected by the control of the rotational angle of the tubular body 10 and/or the accuracy of the rotational angle thereof. To the contrary, when the displacements of the external peripheral surface are detected at positions different in circumferential position by a half circumference length, the diameter of the tubular body 10 can be obtained by comparing two displacements at each instance of the shape measurement. Therefore, the diameter will not be affected by the rotational angle of the tubular body 10. Accordingly, an accurate diameter can be easily obtained without being affected by the accuracy of the rotational angle of the tubular body 10.

[0201]

(4) In the aforementioned embodiment, although a plurality of detecting positions for a displacement of the external peripheral surface of the tubular body 10 are provided, at least one detecting position can be provided.

[0202]

(5) In the aforementioned embodiment, although a photosensitive drum substrate is exemplified as a tubular body 10 to be subjected to the shape measurement, the present invention is not limited to this, but can also be applied to a carrying roller, a developing roller, a transferring roller for use in copying machines, etc. Furthermore, any other tubular bodies can be a measuring object of the present

invention.

[0203]

(6) In the aforementioned embodiment, although the tubular body 10 is rotated by rotating the expansion clamps 20 with the rotation driving sources 26, the rotation of the tubular body 10 can be performed by grasping the tubular body 10 or the pair of expansion clamps 20 with hands to rotate it. Furthermore, a driving roller or the like (not shown) can be brought into contact with a tubular body 10 to rotate it. Furthermore, only one of the expansion clamp is connected to a rotation driving source to rotate the other.

[0204]

(7) In the aforementioned embodiment, although a contact type detecting device which comes into contact with the external peripheral surface of the tubular body 10 is exemplified, such a detecting device is not specifically limited so long as a radial deflection of the external peripheral surface of the tubular body can be obtained.

[0205]

As a displacement detecting device, it may be appropriate to employ a light transmittance type displacement detecting device (light transmittance type optical sensor) which does not come into contact with the external peripheral surface of the tubular body 10. In such a light transmittance type displacement detecting device, as shown in Fig. 16, a pair of a light irradiating portion and a light receiving portion disposed at both sides of the tubular body 10 are disposed so as to face the tubular body 10 from the direction perpendicular to the axial direction of the tubular body 10. Thus, in such a light transmittance type displacement detecting device, The light (e.g., laser beam) irradiated from the light irradiating

portion 38 but not interrupted by the tubular body 10 will be detected by the light receiving portion 39 to thereby detect the surface position of the external peripheral surface 12 of the tubular body 10.

[0206]

As shown in Fig. 16, if the detection area (width) of the displacement detecting device is set to have a height width exceeding the diameter of the tubular body 10, the displacement detecting device can simultaneously detect not only the displacement of one position of the external peripheral surface of the tubular body 10 but also the position facing the position (the positions different in circumferential direction by half circumferential length, or reverse phase position).

[0207]

With this non-contact type displacement detecting device, there is a merit that no damage will be given to the external peripheral surface of the tubular body 10.

[0208]

With the light transmittance type displacement detecting device, the light reaches the light receiving portion 39 by being diffracted near the external peripheral surface of the tubular body 10 which interrupts the light, and therefore detected results in which excessively minute dented portions on the external peripheral surface is omitted can be obtained. Accordingly, there also is a merit that appropriate detection results in which displacements of the external peripheral surface due to excessively minute surface defects are omitted can be obtained.

[0209]

As another displacement detecting devices0, it is possible to employ any detecting device based on various measuring principles, such as a reflection optical sensor capable of detecting the displacement in a non-contact state, an all-purpose image processing CCD camera or line camera capable of detecting the displacement in a non-contact state and applicable to any material, a current-type displacement sensor capable of detecting the displacement in a non-contact state and high in accuracy, high in processing speed, strong in environment and cheap in cost, a capacitance-type displacement sensor capable of detecting the displacement in a non-contact state and high in accuracy, an air-type (differential pressure type) displacement sensor capable of detecting the displacement in a non-contact state, or an ultrasonic type displacement sensor capable of performing a long distance measurement.

[0210]

(8) In the aforementioned embodiment, the tubular body 10 is expanded to the same degree as in the actual use by using the pair of expansion clamps 20 and 20. However, the expansion of the tubular body 10 by the expansion clamp 20 can be smaller than the expansion of the tubular body 10 at the time of the use. In this case, only the expansion smaller than the expansion at the time of actually using the tubular body 10 is made while attaining the supporting state similar to the supporting state in which flanges 80 and 80 are inserted into the vicinities of the end portions of the tubular body 10 at the time of the actual use. Therefore, the influence given to the tubular body 10 at the time of using the tubular body 10 can be decreased.

[0211]

Especially in the case where the tubular body 10 is plastically deformed by being inserted by the flanges 80 and 80 at the time of the actual use, when the pair of the expansion clamps 20 and 20 only give a deformation within the elastic deformation region at the time of the shape measurement, the same shape as the original shape before the shape measurement can be maintained even after the shape measurement of the tubular body.

[0212]

(9) In the aforementioned eleventh embodiment, pressing force similar to the pressing force applied to the tubular body 10 when the flanges 80 and 80 are forcibly inserted into the tubular body 10 is applied by the pair of the expansion clamps 20 and 20. However, the pressing force to be applied to the tubular body 10 by the pair of expansion clamps 20 and 20 can be smaller than the expanding pressing force applied to the tubular body 10 at the time of using the tubular body 10. In this case, only the expansion smaller than the expansion at the time of actually using the tubular body 10 is generated while attaining the supporting state similar to the supporting state in which flanges 80 and 80 are inserted into the vicinities of the end portions of the tubular body 10 at the time of the actual use. Therefore, the influence given to the tubular body 10 at the time of using the tubular body 10 can be decreased.

[0213]

(10) In the aforementioned embodiment, the structure in which the expansion clamp 20 is expanded by the fluid pressure as an operation oil is exemplified. However, it is not limited to fluid pressure in this invention. The driving mechanism to cause the

expansion can be any mechanism capable of obtaining pressing force when clamped. As a driving mechanism to cause the expansion, any mechanism in which material consisting of the expansion clamp changes in volume and the changing amount can be controlled by temperature, electricity, etc. For example, an expanding portion provided in an expansion clamp is heated to be thermally expanded to thereby cause the expansion clamp to be brought into contact with the internal peripheral surface of the tubular body with this expansion force, or further cause the tubular body to be expanded. Alternatively, the so-called piezo-actuator utilizing a material that will be expanded by applying electricity can be employed to cause the expansion clamp to be brought into contact with the internal peripheral surface, or further cause the tubular body to be expanded.

[0214]

(Effects of the invention)

With the method for measuring a shape of a tubular body according to the present invention, a method for measuring a shape of a tubular body, comprises the steps of: inserting a pair of expandable clamps in the vicinity of the end portions of the tubular body, expanding the pair of expandable clamps and bringing them into contact with the entire periphery of the internal peripheral surface of the tubular body, rotating the tubular body together with the expandable clamps about a rotational axis of the pair of expandable clamps, and detecting a radial displacement of the external peripheral surface of the tubular body in accordance with the rotation of the tubular body at at least one position fixed in the peripheral direction of the tubular body. Therefore, the central axis position of the pair of expandable clamps is located almost at the center of a circle formed by the

internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular body. Therefore the radial displacement reflects all influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body.

[0215]

Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened.

[0216]

Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire

circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use.

[0217]

Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement.

[0218]

Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and then rotate the tubular body together with the expandable clamps to detect the displacement of the external peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as small as possible.

[0219]

In cases where the pair of expansion clamps come into contact the positions to be supported at the time of using the tubular body, the shape measurement can be performed as a reference which is a reference of the rotational operation at the time of the actual use. Accordingly, the measurement under the conditions closer to the actual conditions can be performed.

[0220]

In cases where each expansion clamp comes into face-contact with

the entire circumference of the internal peripheral surface of the tubular body with a predetermined contact width, it is prevented the tubular body from being deformed into a shape different from the shape in the actual use due to a partial contact of the expansion clamp against the internal peripheral surface of the tubular body, contributing accurate shape measurement. Furthermore, since no inappropriate deformation will be given to the tubular body, it becomes possible to bring the expansion clamp into contact with the internal peripheral surface of the tubular body with larger pressing force.

[0221]

Furthermore, in cases where the pair of expansion clamps press radially outwardly against the entire circumference of the internal peripheral surface of the tubular body, the pair of expansion clamps can be assuredly brought into contact with the internal surface of the tubular body, assuredly realizing a state close to the rotational state at the time of the actual use.

[0222]

Furthermore, in cases where the pair of expansion clamps deform the tubular body outwardly by pressing the internal peripheral surface of the tubular body outwardly, the supporting state closer to the supporting state at the time of actually using the tubular body 10 to which flanges are inserted into the vicinity of the end portions of the tubular body can be realized, which in turn can attain the rotating state closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0223]

Furthermore, in cases where the deformation of the tubular body due to the pair of the expansion clamps is approximately the same as the deformation at the time of actually using the tubular body, the supporting state more closer to the supporting state in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body 10. This can attain the state more closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0224]

In cases where the pressing force of the expansion clamp pressing the internal peripheral surface of the tubular body is set to be approximately the same as the expanding pressing force applied to the tubular body at the time of using the tubular body, this can attain the supporting state more closer to the supporting state at the time of actually using the tubular body to which flanges are inserted into the vicinity of the end portions of the tubular body at the time of using the tubular body, which in turn can attain the rotating state closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected.

[0225]

Furthermore, in cases where the deformation of the tubular body by the expansion clamp is smaller than that at the time of using the tubular body, the supporting state closer to the supporting state

in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body can be attained. This can attain the state more closer to the rotating state in the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected. Furthermore, since the deformation is smaller that the deformation at the time of the actual use, influences to the tubular body due to the shape measurement can be decreased.

[0226]

Furthermore, in cases where the pressing force of the expansion clamp pressing against the internal peripheral surface of the tubular body is set to be smaller than the tube expanding pressure applied to the tubular body at the time of using the tubular body, the supporting state closer to the supporting state in which flanges are inserted into the end portions of the tubular body at the time of using the tubular body can be attained. This can attain a rotating state more closer to the rotating state at the time of the actual use. Accordingly, by detecting the radial displacement of the external peripheral surface of the tubular body in this state, the deflection caused at the time of the actual use can be more accurately detected. Furthermore, since the deformation is smaller that the deformation at the time of the actual use, influences to the tubular body due to the shape measurement can be decreased.

[0227]

Furthermore, in cases where the tube deformation by the expansion clamp is performed within the elastic deformation region of the tubular body, the deformation of the tubular body during the

shape measurement returns to the original shape, influences to the tubular body due to the shape measurement can be decreased assuredly.

[0228]

Furthermore, in cases where the tube deformation by the expansion clamp is performed until it reaches the elastic deformation region of the tubular body. In this case, even in cases where a tube deformation reaching plastic deformation is given at the time of the actual use, an appropriate deformation for the shape measurement can be given to the tubular body depending in the degree of the actual deformation.

[0229]

Furthermore, in cases where the expansion clamp is configured to be expanded by fluid pressure, large enough expanding force approximately even in the circumferential direction can be obtained, causing the clamp to be brought into contact with the internal peripheral surface of the tubular body. Further, sufficient pressing force against the internal peripheral surface of the tubular body can be obtained.

[0230]

Furthermore, in cases where the expansion ring is provided with an elastic expansion ring to be radially outwardly expanded by fluid pressure so as to be brought into contact with the internal peripheral surface of the tubular body, large enough expanding force approximately even in the circumferential direction can be obtained, causing the clamp to be brought into contact with the internal peripheral surface of the tubular body. Further, sufficient pressing force against the internal peripheral surface of the tubular body can be obtained.

[0231]

The method for measuring a shape of a tubular body according to the present invention comprises: inserting a pair of expandable clamps into the inside of vicinities of both end portions of the tubular body; expanding the pair of expandable clamps to thereby bring the pair of expanded clamps into contact with internal peripheral surfaces of the tubular body along entire circumference thereof; rotating the tubular body together with the expandable clamps about a central axis of the pair of expandable clamps as a rotation axis; and detecting radial displacement of an external peripheral surface of the tubular body caused by a rotation of the tubular body at at least one position positioned outside the tubular body and fixed with respect to a circumferential direction of the tubular body. Therefore, the central axis position of the pair of expandable clamps is located almost at the center of a circle formed by the internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular

body. Therefore the radial displacement reflects all influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement. Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and then rotate the tubular body together with the expandable clamps to detect the displacement of the external peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as

small as possible. Furthermore, since the pair of expandable clamps are expanded by fluid pressure applied therein, sufficiently large expansion force can be obtained approximately evenly along the circumferential direction, and therefore the clamps can be assuredly brought into contact with the interior peripheral surface of the tubular body. Furthermore, it becomes possible to obtain sufficient pressing force for pressing the interior peripheral surface of the tubular body.

[0232]

Furthermore, in cases where the pair of expansion clamps are disposed horizontally, the tubular body takes a posture with the axial direction approximately horizontal, and therefore measured result close to that in the use can be obtained in the case where the tubular body is used in this posture.

[0233]

Furthermore, in cases where the pair of expansion clamps are disposed vertically, it is prevented the axial central portion of the tubular body from being bent due to gravity, enabling the original shape to be measured.

[0234]

Furthermore, in cases where the detecting positions for the displacement include a position other than the positions facing off against the expansion clamps from the outside of the tubular body, the displacement of the external peripheral surface considering thickness of the tubular body can be measured.

[0235]

Furthermore, in cases where the detecting positions for displacement include a plurality of positions outside the tubular

body, the deflection of the external peripheral surface can be measured at plural positions at the outside of the tubular body. By combining the measured results, the shape of the tubular body can be recognized more concretely.

[0236]

Furthermore, in cases where the detecting positions for displacement include a plurality of positions different in axial position of the tubular body, the deflection of the external peripheral surface can be measured at plural positions different in axial position of the tubular body. By combining the measured results, the change of the shape in the axial direction of the tubular body can be recognized.

[0237]

Furthermore, in cases where the detecting positions for displacement include a plurality of positions same in axial position of the tubular body but different in circumferential position, by combining the measured displacement amounts detected at these plural positions, the cross-sectional shape at the axial position can be recognized more concretely.

[0238]

Furthermore, in cases where the detecting positions for displacement include two positions same in axial position of the tubular body but different in circumferential position by a half circumferential length, by combining the measured displacement amounts detected at these two positions, the diameter passing these two positions can be obtained. Thus, the shape of the tubular element can be recognized more concretely.

[0239]

Furthermore, in cases where the detecting positions for displacement include an outside position of the tubular body facing off against at least one of the pair of expansion clamps, the thickness of the tubular body contacting the expansion clamp can be detected. By combining this thickness with the detected results at another detecting positions, more concrete tubular body shape can be obtained. For example it is possible to calculate inspection results in accordance with a conventional inspection in which the displacement of the external peripheral surface of another portions with respect to the external peripheral surface at the vicinities of the end portions of the tubular body as a reference.

[0240]

Furthermore, in cases where the number of the rotation of the tubular body is one or more. In this case, the entire circumferential shape of the tubular body can be detected.

[0241]

Furthermore, in cases where the detection of the displacement can be performed continuously during the entire period or a part of the period for rotating the tubular body, a partial shape change in the circumferential direction of the tubular body can also be detected.

[0242]

Furthermore, in cases where the detection of the displacement can be performed intermittently during the period for rotating the tubular body, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0243]

Furthermore, in cases where the rotation of the tubular body

is intermittently stopped and the detection of the displacement can be performed when the rotation of the tubular body is stopped, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0244]

Furthermore, in cases where the detection of the displacement is performed by using a detecting device which comes into contact with the external peripheral surface of the tubular body, the displacement of the external peripheral surface of the tubular body can be easily detected.

[0245]

Furthermore, in cases where the detection of the displacement is performed by using a detecting device which does not come into contact with the external peripheral surface of the tubular body, the displacement of the external peripheral surface of the tubular body can be detected without harming the external peripheral surface of the tubular body.

[0246]

Furthermore, in cases where the detection of the displacement is performed by irradiating light against the tubular body from the outside thereof and detecting the light passed over the tubular body, the displacement of the external peripheral surface of the tubular body can be detected easily and accurately.

[0247]

Furthermore, as the tubular body preferably applied to the method for measuring a shape of a tubular body according to the present invention, a photosensitive dram substrate can be exemplified.

[0248]

With the method for inspecting a tubular body according to the present invention, a shape of the tubular body in accordance with the method of measuring a tubular body as recited in any one of the aforementioned Items is measured; and based on the measured result it is inspected whether the shape of the tubular body falls within a predetermined allowable range. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0249]

With the method for inspecting a tubular body according to the present invention, the shape of the tubular body is inspected in accordance with the method of measuring a tubular body as recited in the aforementioned method, and it is judged that the tubular body is a finished article when the shape of the tubular body falls within a predetermined allowable range according to the inspection result. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0250]

With the apparatus for measuring a shape of a tubular body according to the present invention, it comprises a pair of expandable clamps to be inserted in the vicinity of the end portions of the tubular body and expanded so as to be brought into contact with the entire periphery of the internal peripheral surface of the tubular body; and at least one displacement detecting device provided outside the tubular body for detecting a radial displacement of the external peripheral surface of the tubular body, wherein the displacement detecting device detects the displacement in accordance with the rotation of the tubular body when the tubular body is rotated together

with the expandable clamp about a rotational axis around the central axis of the pair of expandable clamps. Therefore, the central axis position of the pair of expandable clamps is located almost at the center of a circle formed by the internal peripheral surface of the tubular body. By rotating the tubular body about the central axis of the pair of expandable clamps, it becomes possible to realize a rotating status extremely similar to a rotating status of the tubular body in actual use which is rotated with the internal peripheral surface supported. Therefore, the action of the tubular body detected when rotating is almost equivalent to the action of the tubular body in actual use. Concretely, the detected radial displacement of the external peripheral surface corresponds to the deflection generated in actual use. In detail, the radial displacement of the external peripheral surface to be detected corresponds to the deflection of the external peripheral surface with respect to the near central of a circle formed by the internal peripheral surface at the vicinity of both end portions of the tubular body. Therefore the radial displacement reflects all influences such as the curvature, the uneven thickness, the cross-sectional shape (circularity), etc. of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, it is possible to prevent the accumulation of device differences and/or a request of excessive quality which may occur in the case of separately measuring the thickness of the tubular body. Furthermore, since the deflection of the external peripheral surface to be measured reflects the influence of uneven thickness, the time required to conduct the measurement can be shortened. Furthermore, since the pair of expandable clamps

contact the internal peripheral surface of the tubular body along the entire circumference thereof, the central axis of the pair of expandable clamps can be assuredly positioned at the center of a circle formed by the internal peripheral surface of the tubular body, which can realize a status similar to a rotating status in actual use. Furthermore, since the pair of expandable clamps contact the internal peripheral surface of the tubular body along the entire circumference thereof, even if the expandable clamps make contact with the tubular body with larger pressing force, the pressing force can be distributed in the circumferential direction almost evenly, contributing to accurate shape measurement. Furthermore, it is only requested to insert the pair of expandable clamps inside the tubular body, expand them therein and then rotate the tubular body together with the expandable clamps to detect the displacement of the external peripheral surface. Therefore it is possible to perform the measurement with a simple structure and obtain high accuracy of shape measurement by decreasing the accumulation of measurement errors as small as possible.

[0251]

With the apparatus for inspecting a tubular body according to the present invention, it comprises: the apparatus for measuring a shape of a tubular body; and a comparative means for inspecting whether the shape of the tubular body falls within a predetermined allowable range based on the displacement detected by the displacement detecting device. Therefore, it is possible to discriminate whether the shape of the tubular body falls within a predetermined allowable range.

[0252]

With the system for manufacturing a tubular body according to

the present invention, it comprises a tube manufacturing apparatus for manufacturing a tubular body, the inspection apparatus for a tubular body, an acceptance/rejection discriminating means for discriminating that the tubular body is a completed product if the inspection result by the inspection apparatus shows that the shape of the tubular body falls within the predetermined allowable range. Therefore, it is possible to provide a tubular body having sufficient shape accuracy without causing excessive quality.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Fig. 1 is a front cross-sectional view showing the principle of the method for measuring a shape of a tubular body according to the present invention.

[Fig. 2]

Fig. 2 is a side cross-sectional view showing the same.

[Fig. 3]

Fig. 3 is an operation explanatory view of an expandable clamp.

[Fig. 4]

Fig. 4 is a structural explanatory view of the expandable clamp.

[Fig. 5]

Fig. 5 is an explanatory perspective view showing the usage state of a tubular body (work) to be measured.

[Fig. 6]

Fig. 6 is a front cross-sectional view showing the usage state of a tubular body (work) to be measured.

[Fig. 7]

Fig. 7(a) is a perspective view showing a bent tube as a defect tubular body, and Fig. 7(b) is a cross-sectional view thereof.

[Fig. 8]

Fig. 8(a) is a perspective view showing an uneven thickness tube as a defect tubular body, and Fig. 8(b) is a cross-sectional view thereof.

[Fig. 9]

Fig. 9(a) is a perspective view showing a flattened tube as a defect tubular body, and Fig. 9(b) is a cross-sectional view thereof.

[Fig. 10]

Fig. 10 is a graph showing examples of results of displacement of the external peripheral surface of the tubular body (work) to be measured detected while rotating the tubular body (work).

[Fig. 11]

Fig. 11 is an explanatory view showing the tubular body in which both end portions are deformed into a flattened shape.

[Fig. 12]

Fig. 12(a) is an explanatory view showing a tubular body in which material distribution is uneven in the circumferential direction, and Fig. 12(b) is an explanatory view showing the state in which the tubular body is deformed to be expanded.

[Fig. 13]

Fig. 13 is a functional block showing the structure of an inspection device of a tubular body according to the present invention.

[Fig. 14]

Fig. 14 is a functional block showing the structure of a tube manufacturing system according to the present invention.

[Fig. 15]

Fig. 15 is a front view showing another embodiment of a tube

shape measuring apparatus according to the present invention.

[Fig. 16]

Fig. 16 is a modified example using a not-contact type displacement detecting apparatus.

[Fig. 17]

Fig. 17 is an explanatory view showing the principle of a conventional method for measuring a shape of a tubular body.

[Fig. 18]

Fig. 18 is an explanatory view showing the principle of a conventional method for measuring a shape of a tubular body.

[Description of the reference numeral]

10 tubular body (work)

11 internal peripheral surface

12 external peripheral surface

13 both end potions

14 central portion

20 expansion clamp

21 clamp body

22 oil passage

221 female screw portion

222 operation screw

223 expansion chamber

24 O-ring

25 expansion ring (cylindrical)

26 rotation driving source

30 displacement detecting portion

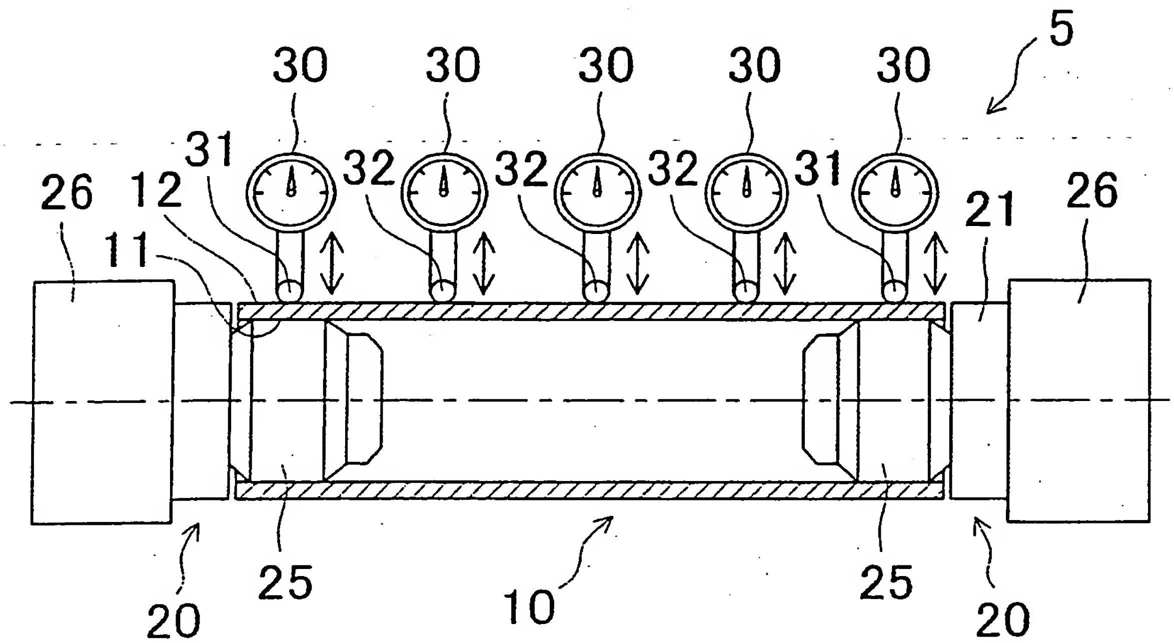
31, 32 detecting positions of displacement

80 flange70

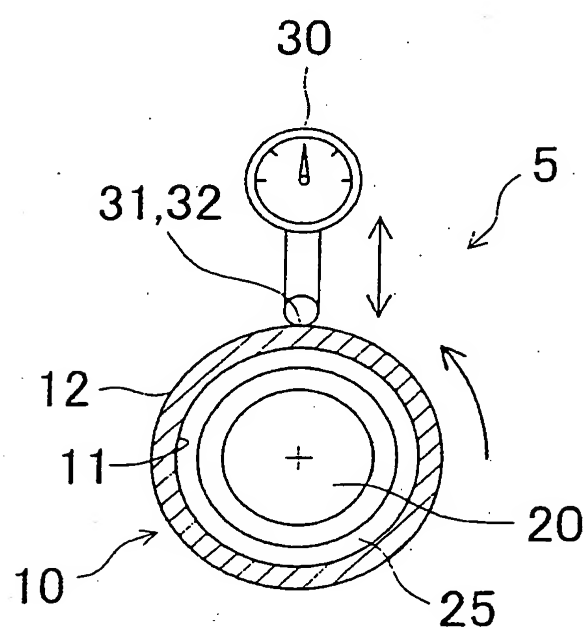
[Name of Document] Drawings

【書類名】 図面

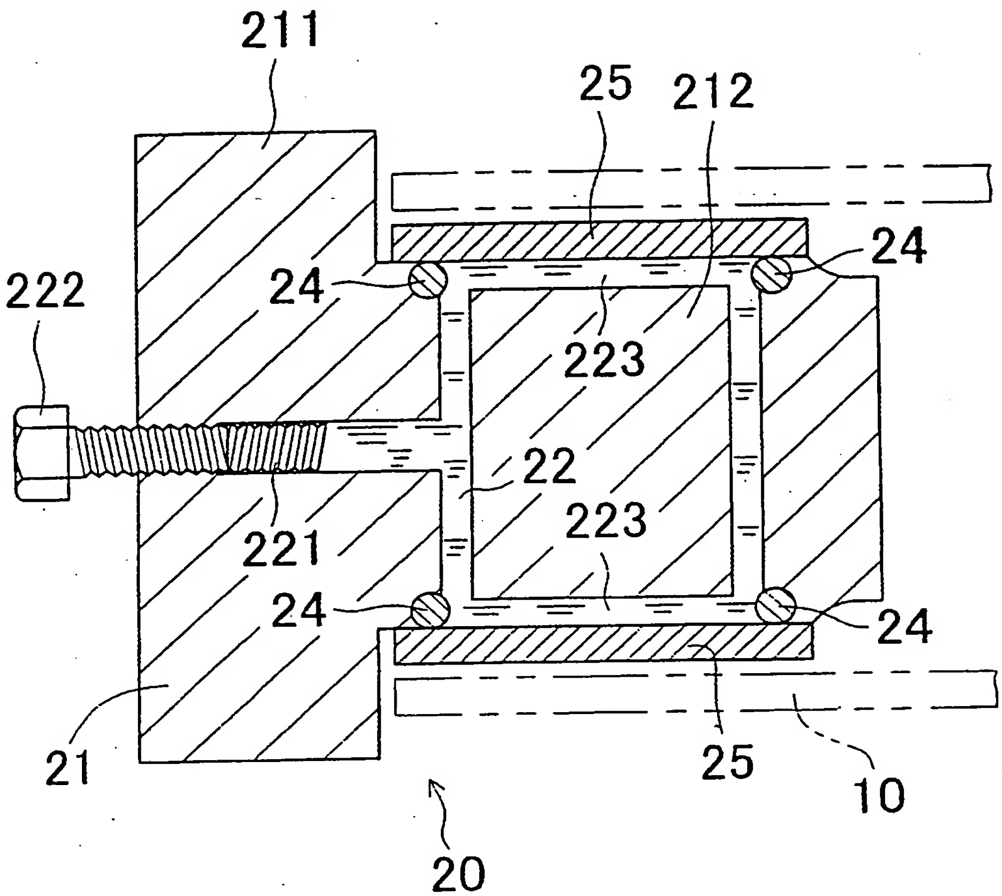
【図１】 [Fig. 1]



【図２】 [Fig. 2]



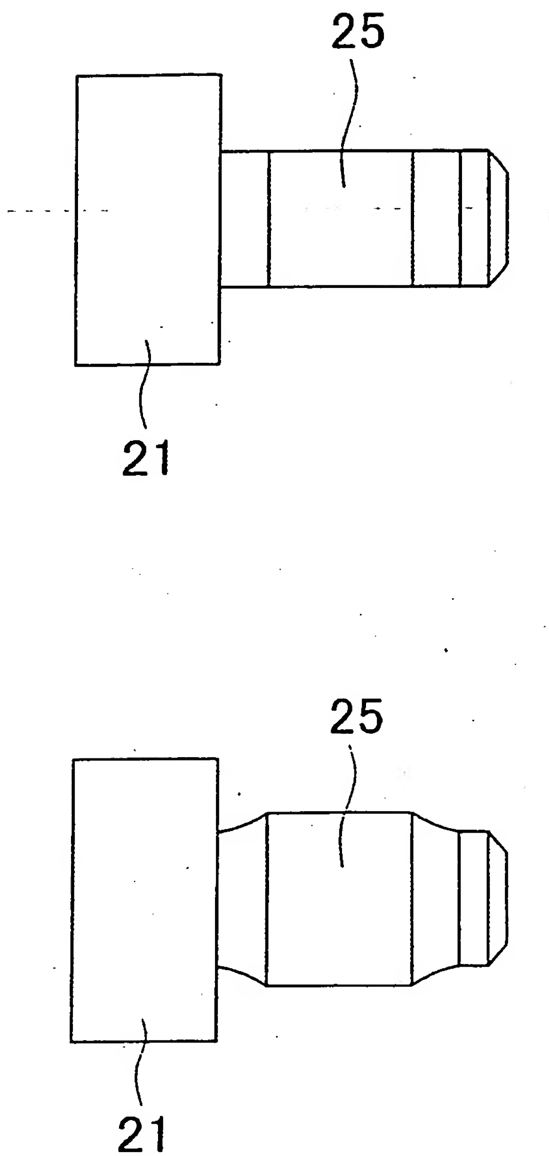
【図３】 [Fig. 3]



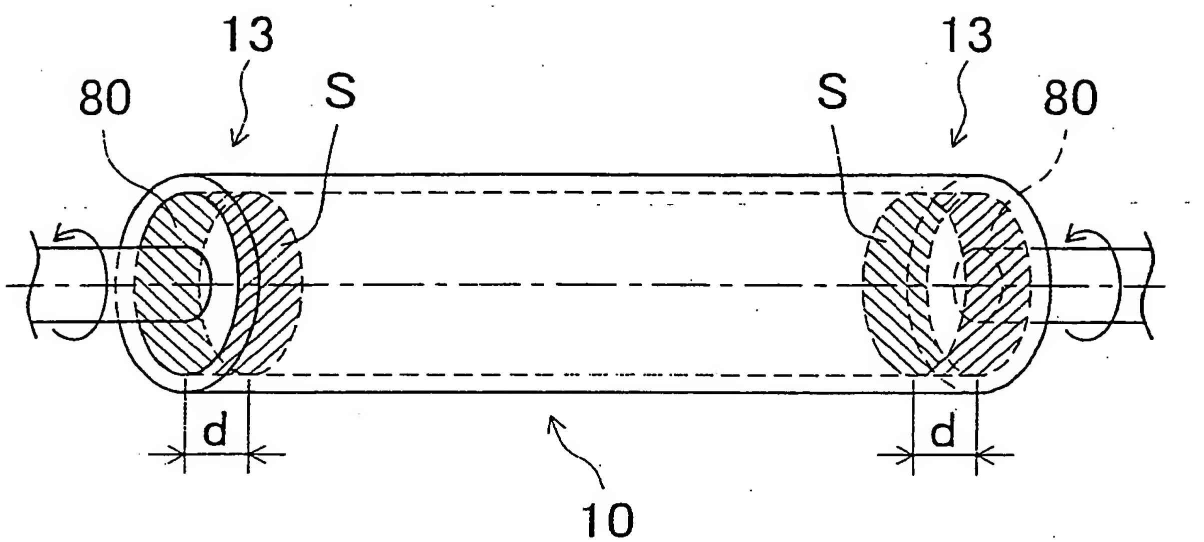
【図4】 [Fig. 4]

(a)

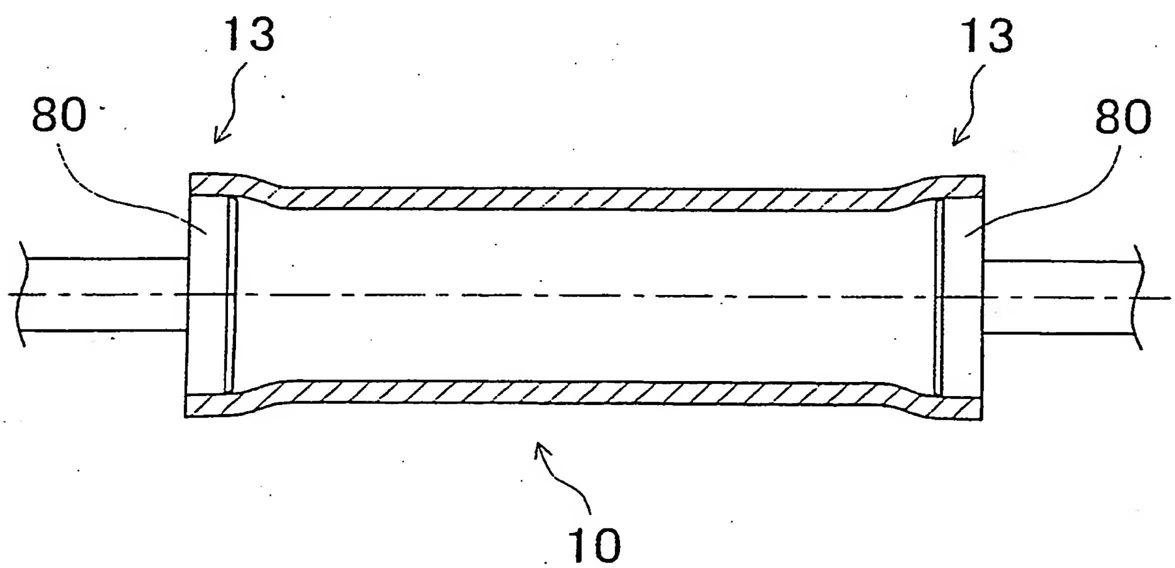
(b)



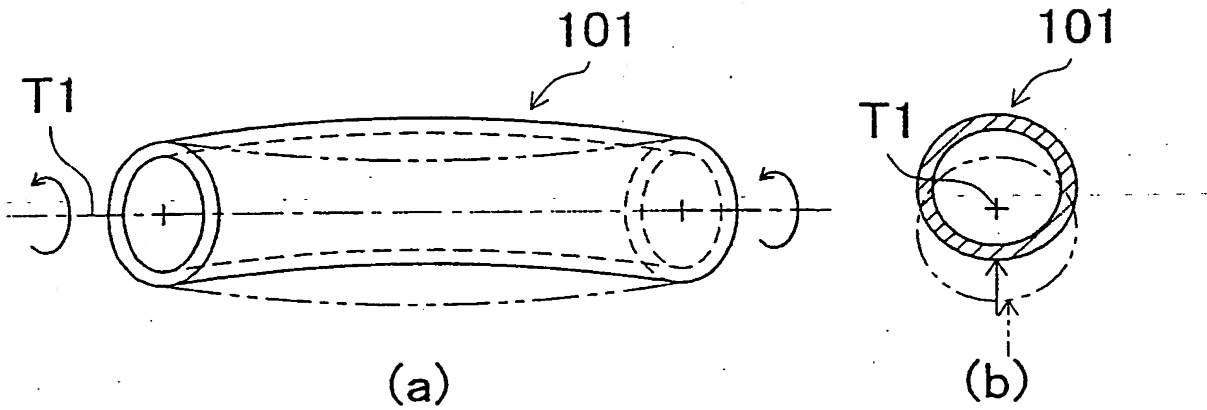
【図５】 [Fig. 5]



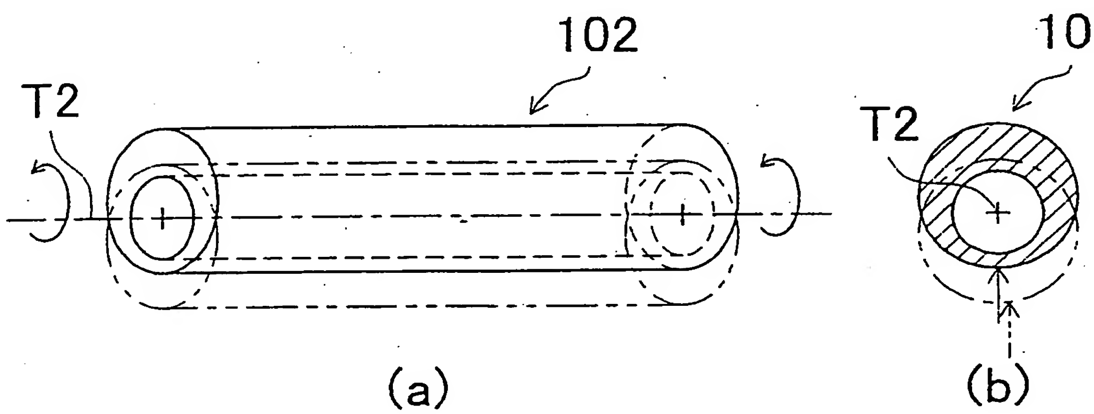
【図６】 [Fig. 6]



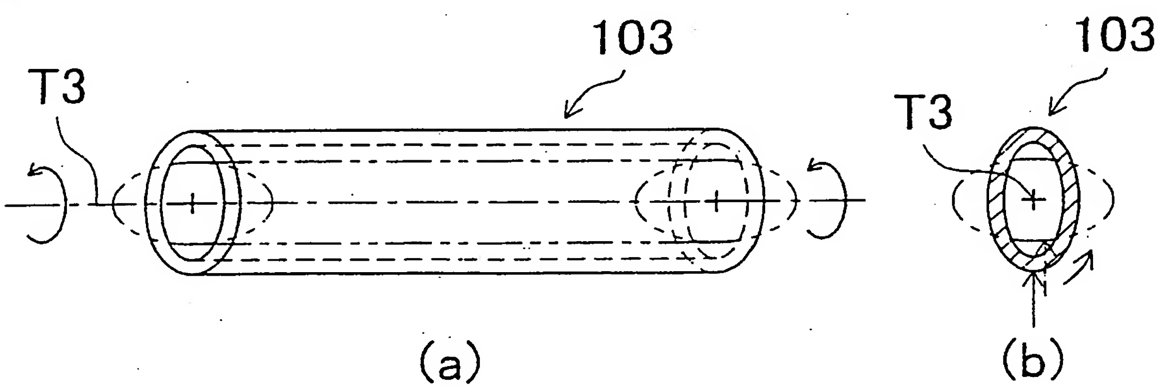
【図7】 [Fig. 7]



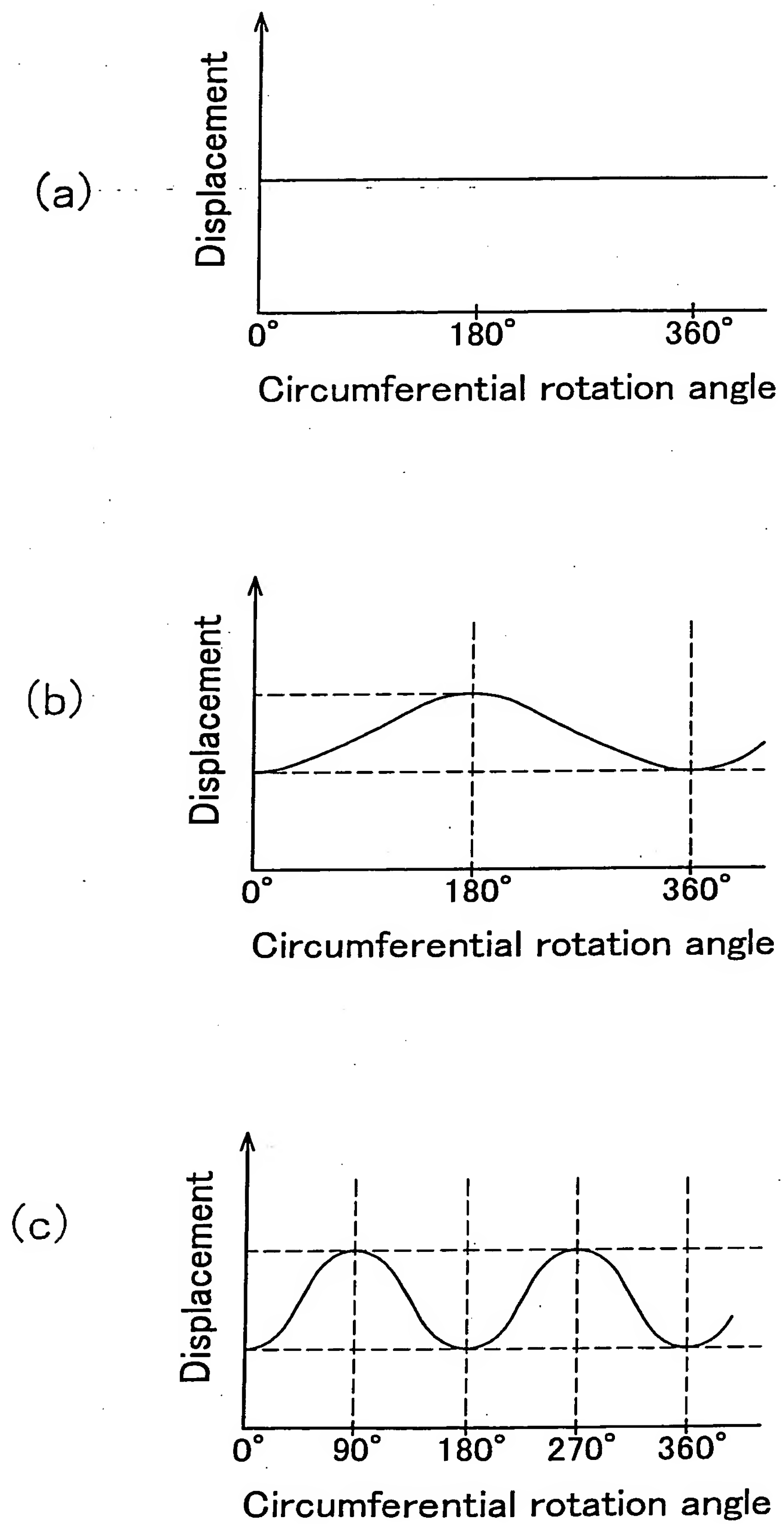
【図8】 [Fig. 8]



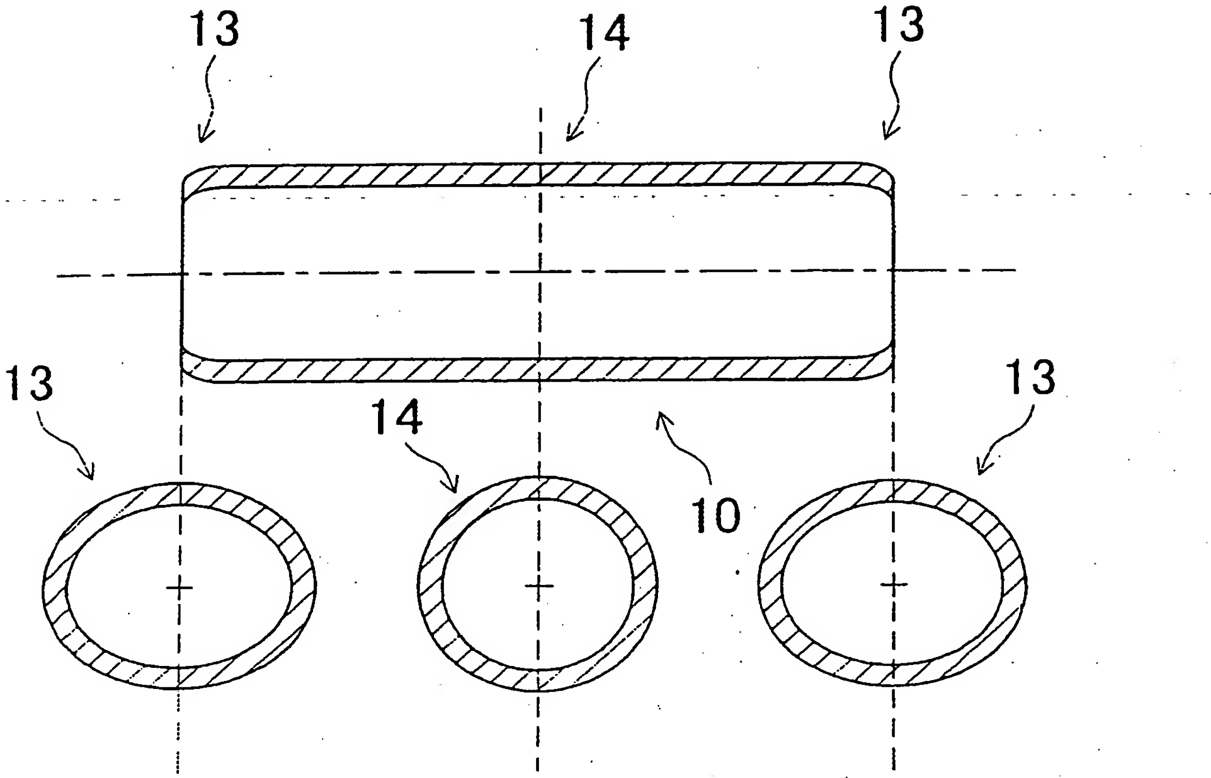
【図9】 [Fig. 9]



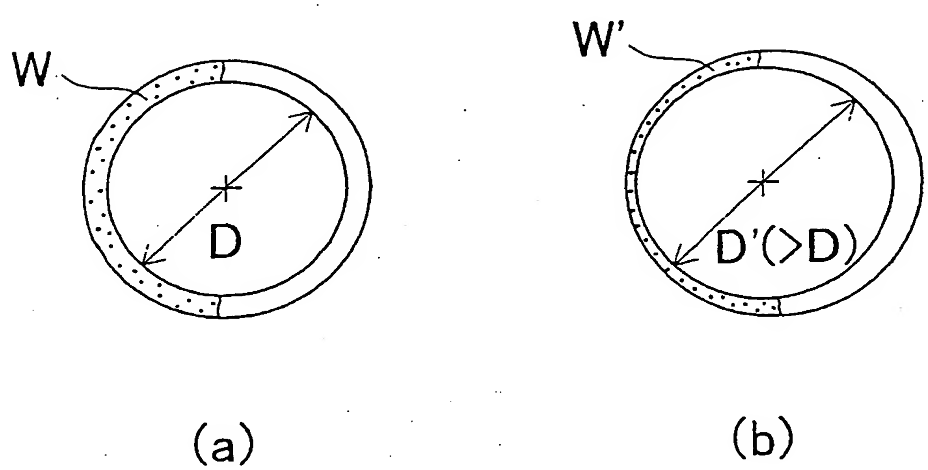
[図10] [Fig. 10]


(a)
Displacement
0°
180°
360°
Circumferential rotation angle
(b)
Displacement
0°
180°
360°
Circumferential rotation angle
(c)
Displacement
0°
90°
180°
270°
360°
Circumferential rotation angle

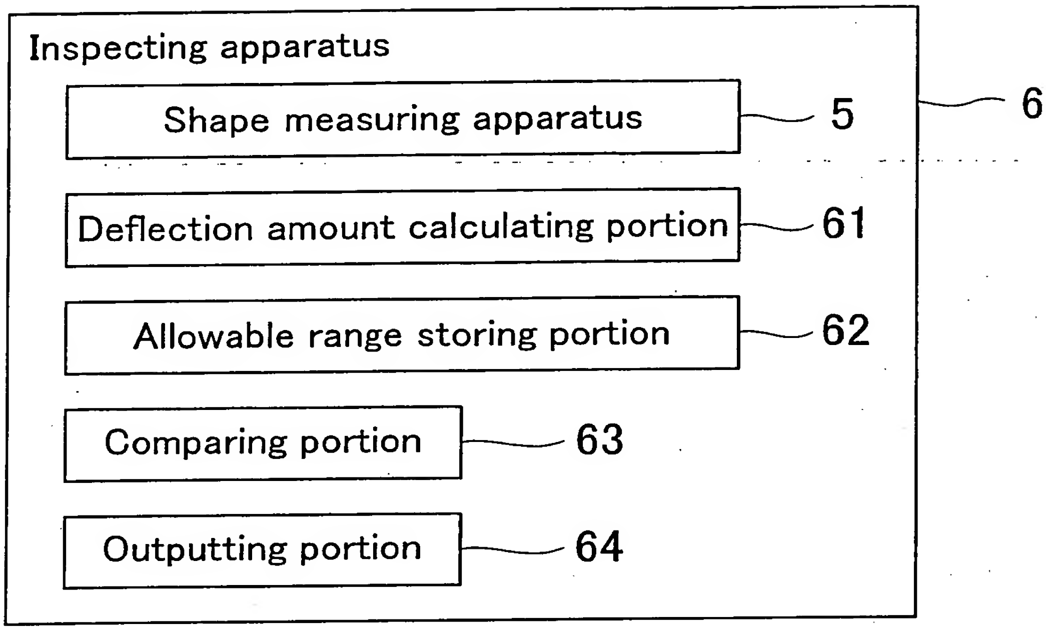
【図11】 [Fig. 11]



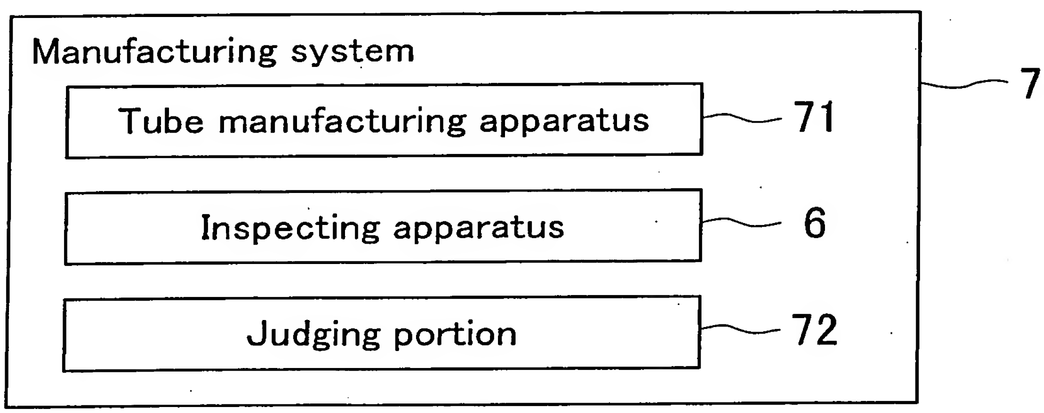
【図12】 [Fig. 12]



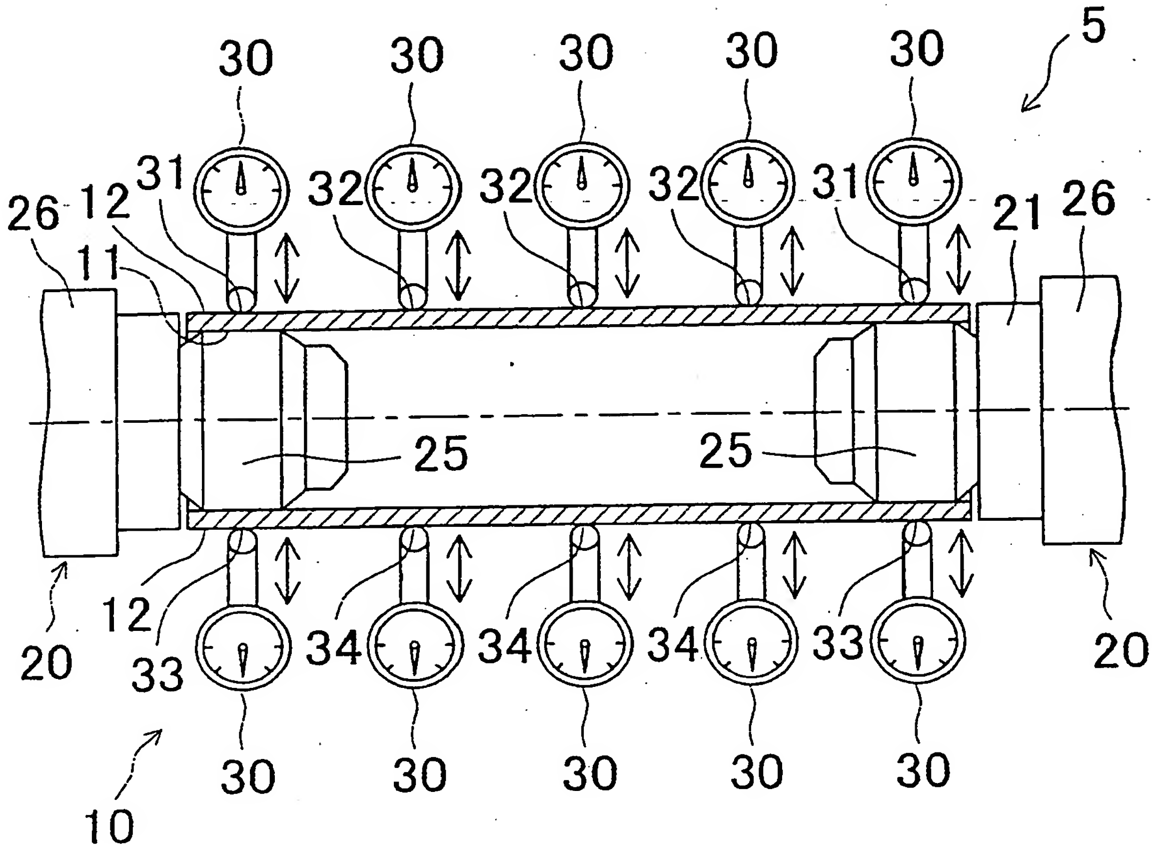
【図13】 [Fig. 13]



【図14】 [Fig. 14]



【図15】 [Fig. 15]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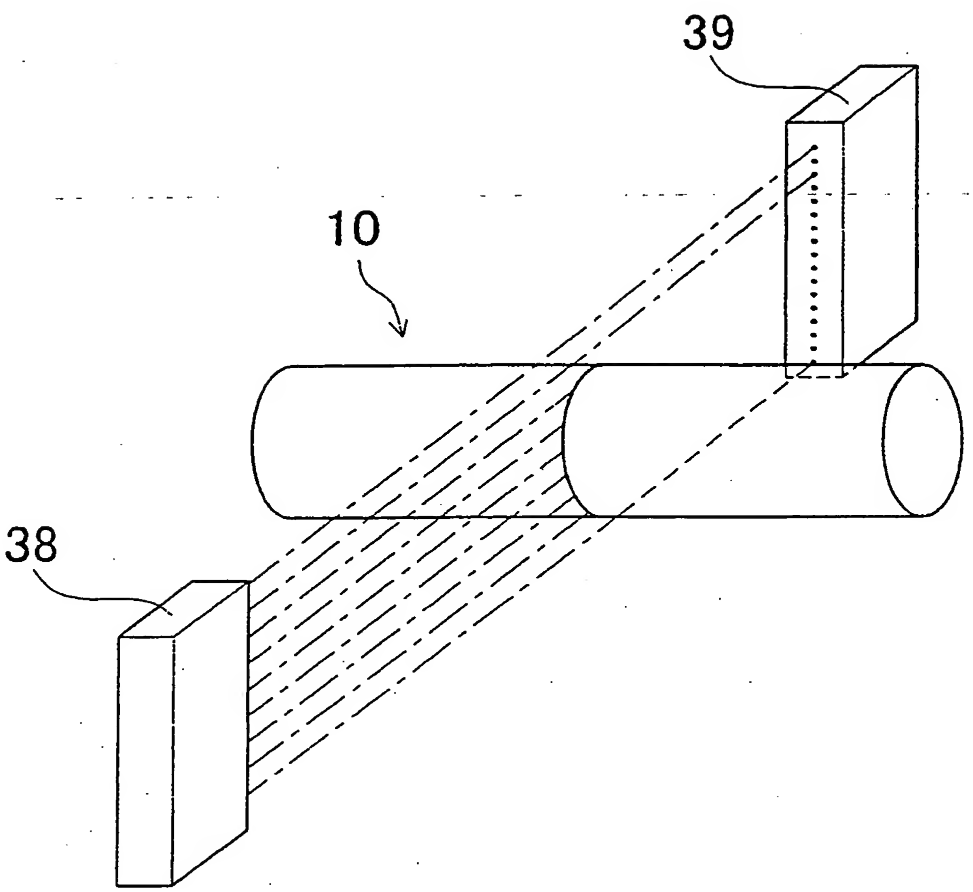
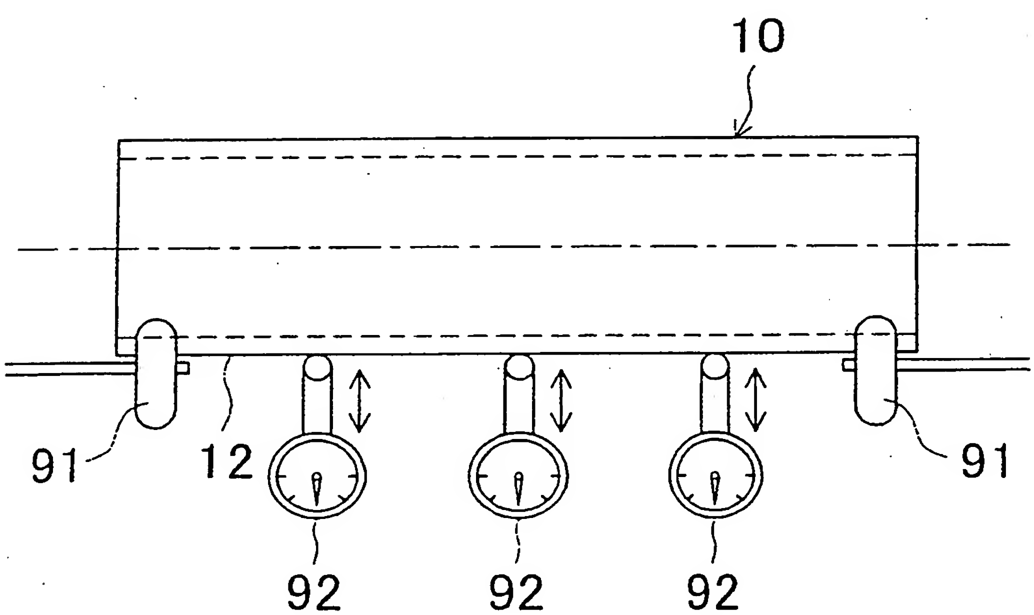
【図１６】 [Fig. 16]



【図１７】 [Fig. 17]



【図１８】 [Fig. 18]